

**F.O.I.A.**

**JULIUS ROSENBERG ET AL.**

***FILE DESCRIPTION***

HO Brothman **FILE**

**SUBJECT** Abraham Brothman

**FILE NO.** 100-365040

**VOLUME NO.** 1

**SERIALS**

thru

58

## NOTICE

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File No: 100-365040Re: Abraham BrothmanDate: 10/86  
(month/year)

Serial	Date	Description (Type of communication, to, from)	No. of Pages		Exemptions used or, to whom referred (Identify statute if (b)(3) cited)
			Actual	Released	
1	9.19.49	NY let HQ	1	1	b1 b2
1	9.19.49	NY Rept HQ	23	23	b1 b2 b7D
1	10.10.49	HQ let NY	1	1	
2	2.6.50	Ladd memo to Director + Encl	2 1/2	2 1/2	
3	4.5.50	NY let HQ	1	1	b1
3	4.6.50	NY Rept HQ	40	39	Updated via b1 b2 b7D
NR	2.8.50	HQ let NY	4	-	see Ladd 65-57449-18
NR	4.17.50	NY let HQ	1	-	see Ladd 65-58845-1090
4	4.28.50	HQ let BA	1	1	b1
5	5.3.50	NY let HQ	1	1	
NR	4.26.50	Belmont memo to Ladd + Encl	17/18	7	see Ladd 65-58845-1091
NR	5.1.50	HQ let NY	5	-	" "

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Rev Rel Deny refer Presumed Proper

File No: 100-365040 Re: Abraham Brothman  
Sept 1Date: 10/86  
(month/year)

Serial	Date	Description (Type of communication, to, from)	No. of Pages		Exemptions used or, to whom referred (Identify statute if (b)(3) cited)
			Actual	Released	
6	5.4.50	CG Rept HQ	13	13	b2 b7cD
7	5.3.50	NY let HQ	3	3	b1
7	5.5.50	HQ TT NY	1	1	
8	5.10.50	NY let HQ + Encl	1/53	1/53	b1
9	5.3.50	NY TT HQ	1	1	
10	5.9.50	HQ TT NY	1	1	
11	5.10.50	HQ TT NY	1	1	b1
NR	5.11.50	IP let HQ	1	-	Dispo in JACO 65-58805-1126
12	5.13.50	NY TT HQ	1	1	
13	5.15.50	NY TT HQ	2	2	b1
14	5.16.50	AT TT HQ	1	1	b1
15	5.17.50	LA TT HQ	2	2	b1

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File No: 100-365040Re: Abraham BrothmanDate: \_\_\_\_\_  
(month/year)

Serial	Date	Description (Type of communication, to, from)	No. of Pages		Exemptions used or, to whom referred (Identify statute if (b)(3) cited)
			Actual	Released	
16	5.17.50	NY TT HQ	1	1	b1
NR	5.18.50	Ladd memo to Director	15	-	Dispr in DocId 65-57449-42
17	5.16.50	PH TT HQ	1	1	
18	5.16.50	NY TT HQ	2	2	b1
19	5.16.50	NY TT HQ	8	8	b1
20	5.16.50	NY TT HQ	6	6	b1
21	5.12.50	HQ TT PH	1	1	
22	5.17.50	NY TT HQ	1	1	b1
23	5.17.50	AL let HQ	1	1	
NR	5.13.50	HQ TT NY	1	-	Dispr in Encl 65-58805-1131
24	5/12/50	- NY let HQ	1	1	b1 b7D
25	?	PH let HQ + encl	1/6	1/6	b1

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File No: 100 - 365040Re: Abraham BrothmanDate: \_\_\_\_\_  
(month/year)

Serial	Date	Description (Type of communication, to, from)	No. of Pages		Exemptions used or, to whom referred (Identify statute if (b)(3) cited)
			Actual	Released	
26	5.20.50	PH let HQ + R/S	1	1	b1
27	5.16.50	NY TT HQ	1	1	b1
28	5.19.50	PH TT HQ	1	1	
29	5.19.50	PH let HQ	1	1	
30	5.12.50	AT TT HQ	1	0	b1
31	5.19.50	LA Rept HQ	11	11	b1
32	5.17.50	AT TT HQ	1	0	b1
32	5.19.50	HQ Cable Legat London-	1	0	b1
33	5.11.50	NY TT HQ	1	1	b1 b7E
34	5.14.50	NY TT HQ	1	1	
35	5.12.50	NY TT HQ	1	0	b1
36	5.11.50	PH TT HQ	1	1	

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File No: 100-365040

Re: Abraham Brothman

Date: \_\_\_\_\_  
(month/year)

Serial	Date	Description (Type of communication, to, from)	No. of Pages		Exemptions used or to whom referred (Identify statute if (b)(3) cited)
			Actual	Released	
37	5.11.50	WFO TT HQ	1	1	
38	5.10.50	PH TT HQ	1	1	
39	5.10.50	NY TT HQ	1	1	b1
40	5.9.50	NY TT HQ	3	3	b1
41	5.9.50	PH TT HQ	1	1	
42	5.15.50	NY TT HQ	1	1	
NR	5.12.50	NH TT HQ	1	-	Dispo in Bolder 65-57449-51
NR	5.15.50	NY TT HQ	2	-	Dispo in Fuchs 65-58805-1153
43	5.19.50	HQ TT NY	1	0	b1
NR	3.21.50	NY let HQ	1	-	Dispo in Fuchs 65-58805-922
NR	5.19.50	CG let HQ	4	-	Dispo in Bolder 65-57449-62
NR	5.19.50	NY TT HQ	1	-	Dispo in Fuchs 65-58805-1206

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File No: 100-365040Re: Abraham BrothmanDate: \_\_\_\_\_  
(month/year)

Serial	Date	Description (Type of communication, to, from)	No. of Pages		Exemptions used or, to whom referred (Identify statute if (b)(3) cited)
			Actual	Released	
NR	5.19.50	HQ TT NY	1	-	Dispt w/ Juchs LS-58805-1206
NR	5.23.50	HQ TT Legat London	1	-	" -1195
44	5.24.50	BS Report HQ	8	8	
45	5.23.50	AT Report + Encl	11/1	11/1	
NR	5.23.50	HQ TT Legat London	3	-	Dispt w/ Juchs LS-58805-1194
46	5.25.50	LA TT HQ	1	1	b1
47	5.19.50	BA let HQ	10	10	b7c per Social Security b2 b7D
48	5.19.50	NY TT HQ	1	1	b1 b7E
49	5.19.50	HQ TT NY	1	1	b1
50	5.21.50	PH TT HQ	1	1	
NR	5.20.50	PH TT HQ	14	-	Dispt w/ Juchs LS-57449-65
51	5.22.50	Ward memo to Belmont	1	1	

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File No: 100-365040Re: Abraham BrothmanDate: \_\_\_\_\_  
(month/year)

Serial	Date	Description (Type of communication, to, from)	No. of Pages		Exemptions used or, to whom referred (Identify statute if (b)(3) cited)
			Actual	Released	
52	5.23.50	NY TT HQ	1	1	b1
53	5.24.50	OM TT HQ	1	0	b1
54	5.25.50	Lab report to PH + Eme	2	2	b1
55	5.20.50	AT TT HQ	1	0	b1
NR	5.25.50	CG let HQ	3	-	Dispo in Folder 65-57449-73
NR	5.26.50	CG let HQ	1	-	Dispo in Folder 65-57449-147
NR	5.26.50	SL Report HQ	4	-	" Folder 65-58805-1249
56	5.27.50	BU TT HQ	1	1	
NR	5.24.50	AQ TT HQ	1	-	Dispo in Folder 65-58805-1239
NR	6.6.50	PH TT HQ	6	-	" Folder 65-57449-359
57	5.22.50	AT Rept HQ	24	22	2 refer Navy
58	5.23.50	NY TT HQ	5	5	b1

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## Office Memorandum • UNITED STATES GOVERNMENT

TO : Director, FBI

FROM : SAC, New York

SUBJECT: ABRAHAM BROTHMAN  
SECURITY MATTER - C~~TOP SECRET~~

DATE: September 19, 1949

SEE REVERSE  
SIDE FOR  
CLASSIFICATION  
ACTIONAPPROPRIATE AGENCIES  
AND FIELD OFFICES  
ADVISED BY ROUTING  
SLIP(S) OFClassification  
6/8/78

Reference is made to the enclosed report of SA FRANCIS J. GALLANT, dated September 19, 1949, at New York City, in the above entitled case, five copies of which are enclosed, herewith.

The Bureau's attention is directed to the information set out on the Administrative Page of the above report. This information is included in accordance with Bureau letter dated August 15, 1949 in the case entitled ~~TOP SECRET~~ ESPIONAGE - R.

In the above mentioned letter, mention is made of one ~~TOP SECRET~~ (S) b1  
It is believed that this individual is possibly identical with ~~TOP SECRET~~ (S) b1  
who is the subject of a Fraud Against the Government investigation entitled, ~~TOP SECRET~~ (S) b1  
"FEDERAL CHEMICAL CORPORATION, REGAL CHEMICAL CORPORATION, THEODORE HEILIG",  
Bureau File 46-9702. In the course of this investigation it was ascertained  
that the subject, BROTHMAN, associated with one ARTHUR PHINEAS WEBER performing  
certain consulting engineering services for HEILIG ~~TOP SECRET~~ (S) b1

It will be noted that HEILIG was indicted in the fraud case, pleaded guilty, and was fined in addition to a jail sentence. ARTHUR P. WEBER was not indicted in this investigation. However, he gave information which assisted in the investigation.

The investigation of BROTHMAN is being continued to ascertain his contacts during the period of October, 1944, in order to identify ~~TOP SECRET~~ (S) b1 mentioned in the Bureau letter of August 15, 1949. In this connection, consideration is being given to interview ARTHUR P. WEBER in view of the fact that he has been closely associated with BROTHMAN during the period 1940 to 1945, and at the present time is not on friendly terms with BROTHMAN. ~~TOP SECRET~~ (S) b1

The above is being submitted for the information of the Bureau.

Encs. (5)

Washington Field (2 encls.)

NY 65-14603

NY 65-14843

ALL INFORMATION ON THIS  
PAGE IS CLASSIFIED ~~TOP SECRET~~  
UNLESS INDICATED OTHERWISE

RECORDED 87

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FJG:MCG

100-95068

Classified by 2855  
Exempt from GDS, Category 2  
Date of Declassification IndefiniteClassified by 2855  
Declassify on: OADR~~TOP SECRET~~Classified by 2855  
Exempt from GDS, Category 2  
Date of Declassification Indefinite

100-365041-1

65-56422-381

FBI  
37 SEP 20 1949



# FEDERAL BUREAU OF INVESTIGATION

Form No. 1  
THIS CASE ORIGINATED AT **NEW YORK**

**CONFIDENTIAL**

NY FILE NO. 100-95068 MCG

REPORT MADE AT <b>NEW YORK</b>	DATE WHEN MADE <b>9/29/49</b>	PERIOD FOR WHICH MADE <b>8/1, 29-31, 9/2, 2, 6-9/49</b>	REPORT MADE BY <b>FRANCIS J. GALLANT</b>
SUBJECT <b>ABRAHAM BROTHMAN</b>		CHARACTER OF CASE <b>SECURITY MATTER - C</b>	
Classified by <b>3042 PWT/IMN</b>		Declassify on: <b>OADR 11/5/80</b>	

## SYNOPSIS OF FACTS:

**ABRAHAM BROTHMAN** born 8/15/13, NYC. Married **NAOMI METT**, 6/15/37. Resides 41-08 42nd Street, Bunnyside, Long Island. Attended schools in NYC; graduated Columbia University with Chemical Engineering Degree. Formerly employed by Hendrick Manufacturing Co.; also Vice-President of Chemurgy Design Corp. Presently conducts own engineering business under the name Abraham Brothman and Associates. Subject associated in business with known Communists. Also signed 1942 CP Nominating Petition. **ELIZABETH T. HENTLEY** has alleged that **BROTHMAN** engaged in Communist espionage apparatus in 1940. Investigation indicated that subject associates with known Communists and also has solicited business from the Russian Government. Has been engaged in engineering work for the Chinese Government and development of plant in Palestine. Results of physical surveillance and information received from confidential sources set forth indicating **BROTHMAN'S** secretary is a known CP member and that **BROTHMAN** frequently associates with Communists, or individuals alleged to be engaged in espionage.

ALL INFORMATION CONTAINED HEREIN IS UNCLASSIFIED EXCEPT WHERE SHOWN OTHERWISE.

Classified by **2365 WAB/Don**  
Exempt from GDS, Category **8**  
Date of Declassification Indefinite

## REFERENCES:

Bureau letter, 3/11/49 ENCLOSURE

APPROVED AND FORWARDED:

*Edward Schmitt*

- COPIES OF THIS REPORT:
- 5 - Bureau
  - 2 - Washington Field (info)
  - 3 - New York (1 NY 65-14603)

**CONFIDENTIAL**

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TOP SECRET

**REFERENCES: (cont'd)**

Letter from Washington Field, 3/22/49.

**DETAILS:**
Background and Personal History

ABRAHAM BROTHMAN was born on August 15, 1913 at New York City. He was married on June 15, 1937 to NAOMI METT, and they have one child, ELSA HARRIET BROTHMAN. He presently resides at 41-08 42nd Street, Sunnyside, Long Island. Also residing with BROTHMAN is his mother-in-law, Mrs. ANN METT. BROTHMAN'S father, HARRY BROTHMAN, resides at 1565 Townsend Avenue, Bronx, New York, with his sister, Mrs. BEATRICE BROTHMAN SCHNEE. BROTHMAN was educated at the John Winthrop Elementary School, DeWitt Clinton High School, and Columbia University where he specialized in accountancy and chemical engineering. He graduated in the class of 1933. (u)

BROTHMAN was formerly employed by the Hendrick Manufacturing Company, 30 Church Street, New York City, and left this organization in July, 1942 and became Vice-President of the Chemurgy Design Corporation, 420 Lexington Avenue. This organization was incorporated in July, 1942 in Connecticut and are the operators of a chemical engineering and manufacturing concern. BROTHMAN resigned from this organization on August 15, 1944 and organized the firm of Abraham Brothman and Associates with offices in Room 1606, 114 East 32nd Street. He was Chief Engineer of this firm which, during the war, were engaged in consulting engineering work for several industrial concerns. In September, 1946, BROTHMAN moved his offices in this above address to 2928 41st Avenue, Long Island City. He also maintains the Abraham Brothman and Associates Laboratory at 8503 57th Avenue, Elmhurst, Long Island. (u)

The above organization is engaged in work particularly for the following concerns:

1. Bridgeport Brass Company, Bridgeport, Connecticut, manufacturers of aerosol bombs for the Armed Forces;
2. The Graver Tank Manufacturing Company, Incorporated, manufacturers of DDT Water Treating for the Army, Navy, and Maritime Commission of the United States.
3. The Palestine Potash, Ltd.
4. Commission of Aeronautical Affairs of the Republic of China. This work consisted of setting up plants for the production of plywood, glues, bomber noses, turrets and domes. (u)

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BROTHMAN in 1945 was the owner of a 1940 tan Pontiac, New York license 5N8976. (u)

### Allegations of ELIZABETH T. BENTLEY

ELIZABETH T. BENTLEY has stated that in about May, 1940, JACOB GOLOS introduced her to one ABRAHAM BROTHMAN, who at that time resided in Nassau County, New York, and who was employed at the Republic Steel Company in Pittsburgh, Pennsylvania, as an engineer. After she met this individual, he told her that he wanted to have some blueprints copies and give the copies to GOLOS who was identified as a known Soviet espionage agent. (u)

BENTLEY stated that she recalled from early Summer of 1940 until the Fall of 1940 she had met BROTHMAN about ten times to obtain blueprints from him. On other occasions, BROTHMAN was contacted by GOLOS. These meetings frequently took place in front of the Moslu Safe Company, 32nd Street and Fifth Avenue, New York City. BROTHMAN would meet BENTLEY and they would usually go to dinner, and during the course of the meal he would turn over these blueprints. BENTLEY recalled that on many occasions the prints that he gave her were copies that had been made from originals; however, it would be necessary on occasions for her to take originals and have copies made from them. She would then give GOLOS the copies and return the originals to BROTHMAN. (u)

Sometime during these meetings, BENTLEY learned from either BROTHMAN or GOLOS that these blueprints were of commercial kettles, which she understood to be some kind of a commercial vat. Sometime during the Fall of 1940 GOLOS told BENTLEY that he was becoming somewhat disgusted in his dealings with BROTHMAN, and told her that he was going to turn him over to someone else. She has never learned from GOLOS, or anyone else, to whom GOLOS directed BROTHMAN.

A photograph of BROTHMAN was obtained from the "Columbian", 1933 Year Book from Columbia University. This photograph was exhibited to ELIZABETH T. BENTLEY and she was able to identify this photograph as the person she had met on several occasions in 1940 as ABRAHAM BROTHMAN who had furnished blueprints to her and JACOB GOLOS. (u)

### Results of Investigation

A physical surveillance was instituted on BROTHMAN on November 28, 1945 and continued until December 28, 1945. In the course of this surveillance BROTHMAN was found to spend a great deal of his time in connection with the activities of his business, Abraham Brothman and Associates. He was observed almost daily going to his laboratory at 8503 58th Avenue, Elmhurst, and his office at 114 East 32nd Street, New York City. (u)

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BROTHMAN was observed in the company of his secretary on numerous occasions. His secretary is MIRIAM MARKOWITZ who resides at 234 Eighth Avenue, New York City. From his association with his secretary, it was indicated that he might be having an affair with her. BROTHMAN was also observed on many occasions with his fellow employees at the laboratory, and also his partner, JULES KORCHIEN, a known Communist Party member who will be later mentioned in the details of this report. (u)

On December 10, 1945 BROTHMAN was observed in the company of one R. MICHEL who was residing at the Madison Square Hotel, New York City, who was later determined to be connected with the Belgium Commission attached with the Belgium Consulate. (u)

On December 12, 1945 BROTHMAN was observed in the company of KORCHIEN at 10 Downing Street, New York City. He was also observed on other occasions having lunch or dinner with KORCHIEN. (u)

BROTHMAN was also observed on December 22, 1945 with an unknown man whom he picked up at the Essex House, New York City. (u)

On December 28, 1945 BROTHMAN, accompanied by MIRIAM MARKOWITZ, met an unknown man at 10:00 P. M. at the Russian Tearoom on West 57th Street, New York City. This individual was later identified as HARRY SLAVIN of 510 West 112th Street, New York City. He was found to be connected with the Histrand Palestine Organization which was founded for the purpose of aiding Jewish people in Palestine. (u)

Confidential Informant T-1, of known reliability, has advised that BROTHMAN was making up drafts and samples for MICHEL and will send IOT proposals to MICHEL in Belgium by mail. He contemplated sending glue solution and dye powder. MICHEL, mentioned here, is believed identical with the individual mentioned in contact with BROTHMAN on December 10, 1945 as set forth in the results of physical surveillance. This same informant advised that MICHEL was leaving for Belgium on September 17, 1945 and his address would be R. V. MICHEL, Sales Promotion Director of Union Carrique Belge, 61 Avenue Louise, Brussels, Belgium. (u)

This same informant advised that the subject maintained a joint bank account with LYNN CHU and C. L. HAN. He has also received \$5,000 in part payment on a chemical process concerning plexiglas and other processes. The balance, an unknown amount, is to be given to the subject upon receipt of a report concerning chemical processes. (u)

Confidential Informant T-1 stated that on December 20, 1945, an individual by the name of STEIGLE (phonetic) of the American-Russian Institute, (u)

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sought an interview with BROTHMAN in view of the fact that he knew what the Russians were doing in chemicals. (u)

Confidential Informant T-1 also advised that BROTHMAN has been devoting considerable time to a project for the Chinese interests. It is believed that this refers to the Commission of Aeronautical Affairs of the Republic of China which is listed as a client of the subject's firm with whom he has the joint bank account. (u)

This same informant advised on December 24, 1945 that BROTHMAN had lunch with Dr. BLUMENFELD who belongs to a political group in which BROTHMAN may become active. BROTHMAN has stated that BLUMENFELD and Dr. WEITZMAN (phonetic), the latter is staying at the Essex House, are not "Jabotinski-ites". The above latter individual is believed to be identical with the man BROTHMAN met at the Essex House on December 22, 1945. (u)

On December 25, 1945, this informant advised that Dr. BLUMENFELD desired BROTHMAN to come to his home at 322 West 72nd Street, Apartment 6-B. BROTHMAN accepted this invitation and expected to go to WEITZMAN'S home with Dr. BLUMENFELD. (u)

Confidential Informant T-1 on December 29, 1945 advised that BROTHMAN had decided not to attend the New Masses' Ball on New Year's Eve because he had been sick with the flu. (u)

Confidential Informant T-1 advised that BROTHMAN was a guest from January 7, 1946 to January 14, 1946 of FRED BRIEHL at his farm in Kingston, New York. BRIEHL is a well known Communist and will be mentioned later in the details of this report. (u)

This same informant stated that BROTHMAN advised Mr. BOWEN of the Bowen Engineering Company of Garwood, New Jersey, that he was developing resins for the Chinese Government. (u)

On January 16, 1946, Confidential Informant T-1 advised that "BILL" BROWDER made an attempt to contact BROTHMAN to interest him in "Distributor's Guide", a publication. (u)

On March 28, 1946, the same informant advised that BROTHMAN was considering an offer given to him by the Kaiser Corporation which consisted of three means by which he might accept association or employment with the corporation. He was offered a position on a straight salary basis, or the Kaiser Corporation would take over Abraham Brothman and Associates, or go to work for the Kaiser Corporation as a consultant engineer and retain his own business. (u)

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On January 22, 1946, Confidential Informant T-1 advised that an individual identified only as MILLY was in contact with MIRIAM MARKOWITZ, secretary to BROTHMAN, and asked her if she was doing anything to better herself as a Communist Party member. MILLY stated that MIRIAM had no excuse now since she does not have to worry about her boss. MILLY stated that she should arrange her work so that she may attend club meetings and assist on picket lines. (u)

Confidential Informant T-1 has advised that BROTHMAN has been in contact with BERNARD O. KOOPMAN, Associate Professor in Mathematics at Columbia University. BROTHMAN is believed to be working on a mathematical formula with KOOPMAN. KOOPMAN was residing temporarily at the Kings Crown Hotel, 420 West 116th Street. (u)

On February 11, 1946 this informant advised that GUS, who is believed identical with GERHART WOLLAN, a subject in an investigation at the New York Office and an associate of BROTHMAN'S, had made his "point" at a meeting which included his club president and section organizer, and that they would take it up with the section committee. (u)

On March 5, 1946 Confidential Informant T-1 advised that BROTHMAN contacted an individual identified as GERTRUDE and they discussed a speech by WINSTON CHURCHILL. GERTRUDE attacked the speech as Fascist propaganda. BROTHMAN stated, in the presence of the informant, that all this is sound and fury in Canada and the United States. Throughout the capitalist world today is full knowledge that they could not engage a war with the Soviet Union. Their own population would not follow them. The world is on fire. The prestige of America and the British Empire is fallen so cheaply within recent weeks. It has been so clearly described that these countries are out for the sole purpose of enslaving the rest of the world. (u)

Confidential Informant T-1 advised that in July, 1946 BROTHMAN was continuing his business at 114 East 32nd Street, and continuing work for the Chinese Government in the development of a type resin. This informant stated that concerning this matter, Mr. WAN (phonetic) had contacted BROTHMAN about a report he desired. On July 8, 1946 WAN stated to BROTHMAN, in the presence of the informant, that he wanted a summary report in order that GEN. CHU (phonetic) might receive it as soon as possible. (u)

On June 18, 1946, Confidential Informant T-1 advised that one LACATER attempted to contact BROTHMAN, who was unavailable. However, he contacted OSCAR VAGO, BROTHMAN'S associate, who advised LACATER that the meeting with POWELL (phonetic) was off, but they would meet later at BROTHMAN'S office to discuss the Soviet Russian proposal. (u)

On July 9, 1946, this informant stated that JULES KORCHIEN, associate of BROTHMAN, had contacted a Mr. NEEDLEMAN (phonetic) at Amtorg. KORCHIEN stated (u)

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to NEEDLEMAN in the presence of the informant that he would like to have him meet ABRAHAM BROTHMAN inasmuch as he was involved in some work, and that he wanted NEEDLEMAN to discuss this work with him. (u)

This same informant advised on July 10, 1946 that BROTHMAN was attempting to locate a Mr. E. W. GOSSELIN in Chicago, Illinois. GOSSELIN is believed to be identical with the head of the Graver Tank Manufacturing Company in Chicago. On this same date, BROTHMAN contacted a Mr. SPRINGER and advised him that he had a contract with the U.S.S.R. in which he believed that GOSSELIN, mentioned previously, would be interested. SPRINGER was requested to locate GOSSELIN and have him contact BROTHMAN. (u)

This same informant advised that on August 7, 1946, BROTHMAN had received a letter addressed to himself from the Government Purchasing Commission of the Soviet Union. The contents of this letter advised that BROTHMAN'S proposals concerning the vitamin plant had been sent to other clients abroad, and that they would advise BROTHMAN when they had heard from these clients. (u)

This same informant advised that a Dr. EDGAR SCHWARZ, a Frenchman, was interested in obtaining information from BROTHMAN concerning engineering problems. (u)

On August 16, 1946 this informant, T-1, advised that C. S. WHAN (phonetic) was preparing a check for BROTHMAN and requested that BROTHMAN submit his report to him. WHAN advised BROTHMAN that Major CHEN had returned to Washington, D. C. This is believed to concern the work being performed by BROTHMAN for the Chinese Government. (u)

On August 19, 1946, Confidential Informant T-1 advised that BROTHMAN, in association with JULES KORCHIEN, was working on a project for the World Tourists, Incorporated, which consisted of renovating their offices. This same informant advised that BROTHMAN held a conference with U. TVERIANOVICH of Amtorg. BROTHMAN advised that he was making a detailed analysis of the vitamin synthesis and desired to discuss the matter further with TVERIANOVICH. (u)

Confidential Informant T-1 advised that BROTHMAN was in the process of moving his office from 114 East 32nd Street, New York City, to the Chatham-Phoenix Building, 2928 41st Avenue, Long Island City, telephone number Ironside 6-5451. Concerning this, it is known that JULES KORCHIEN, BROTHMAN'S associate, will continue to occupy the premises at 114 East 32nd Street. It is understood that KORCHIEN is to draw no salary from the firm of Abraham Brothman and Associates, and that he intends to obtain his own work, and if the projects were large enough, BROTHMAN would work with him. (u)



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This same informant advised on September 13, 1946 that BROTHMAN contacted Mr. KADIONOVICH of Amtorg in New York City who advised BROTHMAN that he was returning to Moscow and was being replaced by Mr. MAIOROV. KADIONOVICH stated that while in Moscow, he would take up the questions that BROTHMAN had requested him to, and that he would send over the news which ABRAHAM BROTHMAN had requested of him, but he had not received any answers from Moscow and planned to take it up in Moscow. (u)

This same informant advised that BROTHMAN, accompanied by KORCHIEN, spent a week at BROTHMAN'S summer place located at Oak Lane and Furnace Dock Road, Peekskill, New York. (u)

This same informant advised that BROTHMAN attended a Foreign Policy speech by HENRY WALLACE on September 12, 1946 at the Madison Square Garden. BROTHMAN stated in the presence of the informant concerning this speech that he never saw anyone make such a big fool of himself as WALLACE had at the meeting. In connection with this above speech, on September 20, 1946 MIRIAM MARKOWITZ, BROTHMAN'S secretary, sent a telegram to President TRUMAN criticizing the ouster of WALLACE, and also sent a telegram to WALLACE urging him to head a third party. Both of these telegrams were signed by BROTHMAN. (u)

Confidential Informant T-2, of known reliability, advised of certain plans that BROTHMAN was working upon at his office. This informant advised that BROTHMAN had a report which was headed "Progress Report on Palestine" and described the proposed set-up for a plant to manufacture TNT which will be suitable for the manufacture of petn, DDT, nitrocellulose, nitroglycerine, nitric acid production, lacquer and alkyl resins. On page three of this report it is indicated that the establishment of a TNT plant was already planned, but in order to shield this operation, other plants were to be operated jointly. As a result, a DDT and alkyl resin plant were also added. (u)

This informant also observed a ten page report by one "RG" on the manufacture of hydrogen-cyanide. (u)

This informant advised there were also present other reports of a technical nature. There was also observed data concerning the manufacture of TNT by a plant to be located in France. This data was to be furnished to Dr. EDGAR SCHWARZ, Ste. d'Electro Chimie, Paris, France. (u)

In a letter observed by the informant to the Government Purchasing Commission of Russia in the United States, there appeared to be a quantity of plant performances. However, no reference was made to any particular plant. (u)

Confidential Informant T-3, of known reliability, advised that on October 29, 1946, BROTHMAN contacted Mr. NEDLEMAN of Amtorg in an attempt to get a hold of TREDANOVICH. On October 30, 1946, this same informant advised that BROTHMAN was in contact with NEDLEMAN at which time NEDLEMAN advised that (u)

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IREKDOVICH "knows all about the situation, knew about it all the time, does not advise you to let on." NEEDLEMAN also stated that the "thing was sent over with his strongest recommendations", and that IREKDOVICH'S final word was that he was sure he would see BROTHMAN "over there". It was not known whether IREKDOVICH was going to Russia, or whether BROTHMAN intended to meet him over there or not. There was no indication that BROTHMAN had plans to leave New York. (U)

Confidential Informant T-2 had advised that BROTHMAN has continued his activities in the development of plastics and has been working with a Chinese known as Mr. WAN (phonetic), believed to be a member of the Chinese Purchasing Commission, presently in the United States attempting to develop industrial projects which are to be operated in the United States for the Chinese. (U)

This same informant has advised that the subject's secretary, in a conference with one GARAVITO in the presence of the informant, stated that BROTHMAN and his associates were being asked to do a plant for a concern in India and that GARAVITO'S services were desired by them. GARAVITO is believed to be a shipping agent. (U)

Confidential Informant T-3 has advised that BROTHMAN has been in contact with HARRY LEVINE of the Commonwealth Plastics Corporation, Leominster, Massachusetts, on several occasions, in regard to the development of industrial projects for a Chinese known as Mr. WAN. This same informant advised that on January 29, 1947 it appeared that negotiations with LEVINE concerning the Chinese matter were definitely broken off. This same informant advised on February 5, 1947 that Mr. WONG, a Chinese, advised BROTHMAN that they were dissatisfied with the terms of his contract; however, would be willing to negotiate if he lowered his terms. BROTHMAN advised WONG that he would discuss the matter with the Chinese. (U)

This same informant advised that BROTHMAN had received a cable from India indicating a contract had been signed, and that they will send the first payment of \$40,000. (U)

This same informant, at a later date, stated that \$5,000 had been remitted by telegraphic transfer through the National City Bank, Long Island City, to BROTHMAN from "VLJX PIETIE" in Bombay, India. It is noted that Bombay Chlorine Products, Ltd., Peoples Building, Bombay, India, has been in contact with BROTHMAN. (U)

Confidential Informant T-3 advised that MIRIAM MARKOWITZ contacted the Jefferson School of Social Science concerning tickets for a school dinner for which BROTHMAN had made reservations. This was on February 21, 1947. This same informant on March 13, 1947 advised that BROTHMAN, in the presence of the informant, spoke to OSCAR VAGO in a disparaging manner concerning President. (U)

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TRUMAN'S speech. This same informant advised that MIRIAM MARKOWITZ contacted NEEDLEMAN of the Amtorg Corporation, New York City, concerning an agreement or contract. NEEDLEMAN is believed to be identical with ISIDORE NEEDLEMAN, legal advisor to Amtorg. (u)

Confidential Informant T-3 advised that MIRIAM MARKOWITZ was again contacting NEEDLEMAN concerning an automobile accident. This same informant advised that MIRIAM MARKOWITZ and NEEDLEMAN, in the presence of the informant, discussed the last business ventures of Abraham Brothman and Associates. MARKOWITZ advised that "the LEVINE deal", mentioned above concerning the Chinese, had fallen through, but that the DDT business in India is "going along nicely". NEEDLEMAN appeared interested in the activities of BROTHMAN. MARKOWITZ also commented concerning Dr. POM who is believed identical with Dr. JACOB POMERANIAN who was visiting this country in July, 1946 and February, 1947. He is believed to be a Polish Jew engaged in the manufacture of plastics in England, and had been in contact with BROTHMAN concerning plastics. (u)

It will be noted here that this informant advised that BERNARD NISHKIL, an associate of BROTHMAN, went to London, England, on April 7, 1947 and returned on April 12, 1947. This source has advised that this trip was made to see Dr. POMERANIAN in London concerning an agreement to manufacture plastics. (u)

On March 28, 1947 an unknown individual contacted BROTHMAN and advised him that he was going to contact HAROLD WINE (phonetic), and wanted BROTHMAN to meet him. This unknown individual stated that WINE was assistant to WENDELL HERGE of the Department of Justice, and that WINE is the representative of the Justice Department to the Atomic Energy Commission and is preparing a chapter of a book now in preparation by the Carls (phonetic) Commission and the University of Chicago on the Economic Consequence of Atomic Energy. The above is believed to be identical with HAROLD HERMAN WINE employed as an economist in the Anti-Trust Division of the Department of Justice. (u)

This same informant, T-3, advised on April 3, 1947 that an individual identified as BOB was in contact with BROTHMAN, advising him that he was interested in making an agreement with him with LOCKLAND CURRIE (phonetic), believed to be the subject of an investigation in this office. (u)

Confidential Informant T-3 advised that on May 23, 1947, JULES KORCHIEN contacted BROTHMAN requesting him to prepare a statement concerning his business and the manufacture of plastics for MAURICE HINDUS who is a former Moscow correspondent for the "New York Herald Tribune". KORCHIEN advised that HINDUS could take this statement to Prague, Czechoslovakia. BROTHMAN at this time discussed with KORCHIEN his desire to make contacts in Central Europe concerning the manufacture of plastics. (u)

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It will be noted here that MAURICE HINDUS, mentioned above, is a close contact of URSULA WASSERMAN, a suspected espionage agent and also a contact of the subject, BROTHMAN. (u)

On November 28, 1945, Mr. J. C. HEADDER of the National City Bank, New York City, advised that BROTHMAN had an account at the 32nd Street Office of the National City Bank, 1 Park Avenue, in the name of Abraham Brothman and Associates. This account was opened on September 5, 1944 with a deposit of \$270, made up of various checks. The banking records indicated that this was a joint partnership made up of ABRAHAM BROTHMAN, JULES KORCHIEN, GERHART WOLLAN, and OSCAR J. VAGO. There was a fifth partner, EMIL Z. PARISH, whose name had been removed. (u)

In the period checked, this account was deemed to be active and included deposits of checks by the Chase National Bank and Trust Company, Continental Bank and Trust Company, National Bank and Trust Company, Chicago, Illinois, and the First National Bank and Trust Company, Bridgeport, Connecticut. This would indicate that these were monies paid to the Abraham Brothman and Associates from their accounts with the Bridgeport Brass Company and the Graver Tank Manufacturing Company. (u)

Mr. HEADDER advised that ABRAHAM BROTHMAN had opened up a personal checking account at this branch on August 8, 1944. This was made into a joint account on July 16, 1945 with his wife, NAOMI BROTHMAN. The initial deposit amounted to \$53.85. It was noted that MIRIAM MARKOWITZ had power of attorney to sign checks on this account. This account was active and various withdrawals were made of a very small nature. (u)

Mr. HEADDER also stated that ABRAHAM BROTHMAN opened an account with one IRVING BENNETT on May 3, 1945 with a deposit of \$1,000, being a check drawn on the account of Abraham Brothman and Associates. This account remained inactive until it was closed on June 8, 1945. This account was given the address in care of the Syntomatic Corporation, 114 East 32nd Street. This firm was believed to be engaged in the manufacture of aromatic chemicals. (u)

This bank also maintained an account in the name of Abraham Brothman and Associates, and/or Colonel LYNN CHU or Mr. C. S. WAN. This account was opened with an initial deposit of \$16,000 on June 4, 1945, consisting of a check drawn on the Bank of China, 40 Wall Street, New York City. There was a deposit made on this account on July 18, 1945 and another in August, 1945 to the amount of \$7,000 on each occasion. There have been no withdrawals made from this account through the period checked. (u)

It is noted that during the period BROTHMAN was furnishing the blueprints to GOLOS and ELIZABETH BENTLEY, he was employed by the Hendrick Manufacturing Company. Confidential Informant T-4, of known reliability, advised that (u)

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This corporation was chartered in Pennsylvania in 1941 and was engaged solely in war work, manufacturing perforated metals, tanks, stacks, shoots and cones. Confidential Informant T-4 advised that Abraham Brothman and Associates of 114 East 32nd Street, New York City, was a partnership with the following individuals listed as the active partners:

ABRAHAM BROTHMAN, 4108 42nd Street, Bunnyside, Long Island;

GERHART WOLLAN, 28 Reeve Place, Brooklyn, New York;

JULES KORCHIEN, 46 Washington Square South, New York;

OSCAR J. VAGO, 66-07 99th Street, Forest Hills, Long Island. (u)

WOLLAN is native born and graduated from Luther College and the University of Idaho with a Master's Degree in physics in 1930. In 1945 he was thirty-four years of age. (u)

VAGO is a naturalized Hungarian, a graduate of the University of Budapest, in Hungary, in 1919 with a Civil Engineer's Degree. (u)

Confidential Informant T-5, of known reliability, advised that on January 28, 1948, [REDACTED] b1

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On February 2, 1948, according to Confidential Informant T-5, [REDACTED] b1

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The following individuals have been associated with BROTHMAN, or have been in contact with him on various occasions as mentioned before in the details of this report. (u)

JULES KORCHIEN

KORCHIEN is a known Communist Party member and is a contact of numerous Communists and suspected Communists in New York City. He is the International Vice-President of the Federation of Architects, Engineers, Chemists, and Technicians, an alleged Communist dominated union. In 1945 he was delegate to the Greater New York CIO Industrial Union Council and a member of the Architect Committee of the National Council of American-Soviet Friendship. KORCHIEN is the subject of an investigation in this Office. (u)

Confidential Informant T-6, of known reliability, advised that KORCHIEN was employed by the Chemurgy Design Corporation until becoming a partner in the BROTHMAN enterprise which represents his first entry into business on his own account. This above informant has stated that the Chemurgy Design Corporation was located at 420 Lexington Avenue, the officers of which corporation were HENRY A. GOLYWNNE, ABRAHAM BROTHMAN, Vice-President, and ARTHUR P. WEBER, Secretary. This corporation was organized in Connecticut on July 7, 1942. GOLYWNNE, this informant advised, is a native of England and is not a citizen. He has been the organizer of various corporations. This informant advised that BROTHMAN resigned from Chemurgy Design Corporation and organized his own firm. (u)

OSCAR J. VAGO

VAGO is another business associate of the subject. He is a native of Hungary and a naturalized American citizen. Confidential Informant T-6 stated that he had been in the employ of the Chemurgy Design Corporation until entering business with BROTHMAN. (u)

Confidential Informant T-7, of known reliability, has advised that OSCAR J. VAGO, with alias, OSZKAR VAGO, is a structural engineer and was naturalized in 1938. He is known to be a member of the CIO Council and in March, 1944 was known to be a member of the Rego Park Club of the Communist Party of Queens. (u)

GERHART WOLLAN

WOLLAN is also native born, and, as stated previously, has a degree from the University of Idaho. He was formerly employed by the Chemurgy Design Corporation prior to going into business with the subject. (u)

Confidential Informant T-8, of known reliability, advised that WOLLAN is a resident at 28 Reeve Place, Brooklyn, styling himself as a physicist and a member of the Federation of Architects, Engineers, Chemists and Technicians, (u)

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Metropolitan Chapter #31, and in January, 1943, was known to be a member of the Kensington Club, Communist Political Association, Brooklyn, New York. (u)

EARL C. BAKISH

According to Confidential Informant T-6, BAKISH is a native born citizen and a graduate of the University of California in 1938 with a Mechanical Engineering Degree. He also was formerly employed by the Chemurgy Design Corporation prior to entering business with the subject. (u)

WILLIAM BROWDER

BROWDER was known to have been in contact with the subject on January 16, 1946 and is identified as the brother of EARL BROWDER, former National Chairman of the Communist Party, U.S.A. He attempted to interest BROTHMAN'S office in his new pamphlet, "Distributor's Guide". (u)

ROSE REUBEN

ROSE REUBEN on May 15, 1946 was connected with the American-Russian Institute and had contacted BROTHMAN to suggest or recommend some person who knew technical Russian. REUBEN advised that they needed a person to translate from Russian into English the technical phrases of Soviet industries. BROTHMAN recommended one BILL BOHALL who resided on Aqueduct Avenue, Bronx, and had been utilized by BROTHMAN as a translator of Russian. (u)

FRED BRIEHL

It will be recalled that the subject vacationed at FRED BRIEHL'S farm in early 1946. BRIEHL is a well known Communist who has been investigated by this office. He is known to be registered with the Communist Party and has run for elected office on the Communist Party ticket. He is reported to hold a high position in the State Organization of the Communist Party. In July, 1945, he was elected unanimously to the New York Up-State Cultural Section at the State Communist Political Association Convention. (u)

The files of the New York Office indicate that BROTHMAN, while residing at 4108 42nd Street, Long Island, New York, signed a 1943 Communist Party Nominating Petition. (u)

It was also noted by Confidential Informant T-9, of known reliability, that BROTHMAN interested himself in such reading matter as the April, 1945, issue of "Political Affairs"; the textbook on Dialectical Materialism entitled, "Economics Barbarism"; "300,000,000 Slaves and Serfs" by KUCZYNSKY, and the "American Review of the Soviet Union", a quarterly published by the American-Russian Institute. (u)

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On May 29, 1947, ABRAHAM BROTHMAN was interviewed concerning the above allegations of ELIZABETH BENTLEY in his office, Room 1212, 2948 41st Avenue, Long Island City, New York. BROTHMAN was first questioned regarding his submitting information or furnishing blueprints to any individuals who might have connections with a foreign government. BROTHMAN stated that he had furnished blueprints to a number of individuals, and it was a common practice in the engineering field to submit blueprints to certain individuals who might possibly be in a position to obtain contracts for a firm. (u)

BROTHMAN was then specifically questioned as to whether or not he had been acquainted with an individual by the name of JACOB GOLOS. BROTHMAN stated that he could not recall this name, and a picture of GOLOS was exhibited to him. BROTHMAN denied knowing GOLOS at this time. Thereupon a picture of informant GREGORY was exhibited to BROTHMAN. BROTHMAN identified GREGORY as an individual whom he knew as "HELEN". BROTHMAN was thereupon vigorously questioned as to his acquaintanceship with HELEN. He then admitted that he did recognize the photograph of GOLOS, but was unable to state the name of this individual. BROTHMAN then related the following concerning his knowledge of JACOB GOLOS and HELEN: (u)

According to BROTHMAN, sometime in 1938 or 1939 an individual came to him at his office at 114 East 32nd Street, at which time BROTHMAN was operating a firm under the name of the Republic Chemical Machinery Company, which company was associated with the Hendrick Manufacturing Company at Carbondale, Pennsylvania. This individual told BROTHMAN that he had contacts with the Russian Government for BROTHMAN, if BROTHMAN would turn over to him blueprints of certain products BROTHMAN was working on at that time. BROTHMAN stated that the blueprints were his own property and they were for the most part blueprints of shafts, vats, and other equipment necessary in the operation of a plant manufacturing chemicals. (u)

According to BROTHMAN, GOLOS visited his office on several occasions and sometime following his original visit he introduced him to an individual known only as HELEN. BROTHMAN stated that he was under the impression that HELEN was secretary to GOLOS. GOLOS advised BROTHMAN that HELEN would in the future obtain the blueprints which he had been accustomed to turn over to GOLOS. (u)

HELEN visited BROTHMAN'S office over a dozen times during 1938-1939-1940 and sometime in 1940 HELEN stopped coming to his office and another individual named HARRY GOLD came to his office and said he represented GOLOS, the individual BROTHMAN had already identified as the man who made the original contact with him. GOLD visited BROTHMAN'S office on a number of occasions during 1940 and 1941. BROTHMAN stated that GOLD at that time was living in Philadelphia and used to make the trip to New York approximately every three weeks and obtain these blueprints from BROTHMAN. He said that to the best of his recollection the last time GOLD picked up the blueprints was late in 1941 or early in 1942. (u)



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BROTHMAN was then questioned as to the whereabouts of HARRY GOLD, to which he replied that GOLD is presently employed by him as a chemist in his laboratory in Kibburest, Long Island. BROTHMAN emphatically stated that GOLD was the last individual to pick up any blueprints or material which was to be furnished to GOLOS. He also stated that he did not know the present whereabouts of GOLOS and denied that he was ever contacted by any other individuals other than HELEN and GOLD as individuals who represented GOLOS. (u)

BROTHMAN was questioned as to the nature of the blueprints that he had turned over to GOLOS, at which time he displayed the blueprints, copies of which he still had in his offices, and an examination of the blueprints was made and it was determined that they were all concerned with blueprints of shafts, filters, vats, and other machinery used in the manufacture of chemicals. BROTHMAN stated that some of the blueprints which he turned over to GOLOS and HELEN as well as to GOLD were returned to him, but the others were retained by them. He emphatically denied that he had ever turned over any blueprints which were of a restricted or secret nature pertaining to the war effort of the United States, or any plans which the United States might be concerned with at that time. (u)

Relative to the Hendrick Manufacturing Company at Carbondale, Pennsylvania, BROTHMAN stated that he himself had founded the Republic Chemical Machinery Company which was set up as an engineering and designing company dealing solely with instruments and material to be used in the manufacture of chemicals. He stated that at the time he had formed the Republic Chemical Machinery Company he was associated with the Hendrick Manufacturing Company and worked with that company until 1942. BROTHMAN added that all of the blueprints which had been turned over to the individuals mentioned hereinbefore were his own personal property belonging solely to the firm that he had founded. (u)

BROTHMAN was specifically questioned as to how he had become acquainted with JACOB GOLOS. He replied that possibly GOLOS knew of his firm through advertising in the various chemical magazines. He emphatically stated that this was the only possible way that GOLOS would get in touch with him and denied that anybody had ever sent GOLOS to him. BROTHMAN then stated that it was a common practice in the engineering field to turn over blueprints to various individuals in an effort to obtain contracts. He also stated that this was his sole purpose in turning over the blueprints to GOLOS; namely, that GOLOS had stated that he was in a position to obtain contracts from the Russian government. (u)

The following signed statement, the original of which is being retained in the New York Office, was obtained from BROTHMAN:

New York, N.Y.  
May 29, 1947 (u)

"I, Abraham Brothman, make the following voluntary statement to Donald (u)

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"I, Shannon and Francis D. O'Brien, whom I know to be Special Agents of the Federal Bureau of Investigation. No threats or promises of any nature were made to me to make this statement. I know that what I say may be used against me at any time in a court of law. (u)

5-23-42  
"In 1938 or 1939 a man whose name I do not recall but whose picture was shown to me today by Mr. Shannon & Mr. O'Brien, came into my office at 114 E. 32 St. where I own and operated the Republic Chemical Machinery Co. which was associated by contract with Hendrick Manufacturing Co. This man said he had contacts with the Russian government and he could get me contracts with the Russian government. I turned over several blue prints to him; these blue prints were my own for the most part and the purpose of turning them over to him was to obtain contracts. Shortly after this man came to my office a woman by the name of Helen came to my office and said she represented this man, whose picture I have identified; I believed that this woman was the secretary of the man whose picture I identified. I have identified Helen as the girl whose picture Mr. Shannon & Mr. O'Brien have shown to me. This Helen came to my office over a dozen times during 1938, 1939 & 1940. Then around 1940 another man whose name is Harry Gold came to my office and he said he too represented the man whose picture I identified. Both Helen and Harry Gold would pick up blue prints from me for this man whose picture I have identified. Harry Gold is now employed by me as a chemist. The blue prints were sometimes returned by Helen and Harry Gold but not all of them. I still have the original of most of the blue prints that I turned over to them. Harry Gold made his last pick up of blue prints late in 1941 or early in 1942. (u)

"Sometime in 1938 or 1939 I became associated with Hendricks Machinery Co. and did work with them until 1942. The blue prints were my own and not Hendricks. (u)

"I once contacted the man whose picture I have identified at a phone listed to a Mr. Chester and the telephone exchange was Watkins to the best of my recollection. I often met this man and Helen, his Secretary at various restaurants in the mid-town area in New York City. (u)

"I have not seen this man whose picture I identified since 1941 or 1942. (u)

"I have read the above three page statement and it is true to the best of my recollection. I have read and signed page 1 and it is true to the best of my recollection. I have read and signed p. 2 and it is true to the best of my recollection. I now sign p. 3 and it is true to the best of my recollection. (u)

1/5/ Abraham Brothman

Witnessed

Donald E. Shannon, Special Agent, F.B.I., N.Y. City  
Francis D. O'Brien, Special Agent, F.B.I., N.Y. City

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BROTHMAN was questioned regarding his activities and contacts with the Russian government. He stated that he had submitted various contracts to the Soviet Purchasing Commission and the Amtorg Trading Corporation but that he had never obtained a contract from either of these two agencies representing the Russian government. He offered the information that he had recently obtained a contract from the Chinese government and that he had obtained this contract by the same means that he had used in obtaining all of his contracts; namely, by submitting plans and blueprints to individuals representing the Chinese government, and they had given him the contract for the development of a material which they hoped will eventually reduce the cost of manufacturing lacite. (u)

BROTHMAN was then specifically questioned as to whether or not he had ever been associated with the Communist Party or had attended any of the meetings or Communist affairs. BROTHMAN replied that he was a member of the Young Communist League during the time that he attended Columbia University; namely, in 1933. BROTHMAN stated that he did not attend any Communist Party meetings at the present time, nor was he actively engaged in any Communist Party affairs. (u)

BROTHMAN was then questioned as to whether or not he had ever suspected that JACOB GOLOS was engaged in espionage activities. BROTHMAN replied that during the time that the Canadian espionage case broke in Canada in 1946 in reflection he became suspicious of GOLOS and thought possibly he was engaged in the type of activity that existed in Canada. (u)

BROTHMAN offered the information that he was a member of the Political Action Committee and had attended meetings of that organization. (u)

A Grand Jury subpoena was issued on July 10, 1947 ordering BROTHMAN'S attendance before the Federal Grand Jury sitting in the Southern District of New York on July 16, 1947. However, this attendance was later changed to July 22, 1947 when BROTHMAN testified before the Grand Jury. (u)

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A mail cover was placed on the subject with the following results:

DateName

January 4, 1946

~~H. SLAVIN~~  
510 West 112th Street  
New York City

January 22, 1946

Music Room  
129 West 44th Street  
New York City

It will be noted here that this is the business owned and operated by ERIC BERNAY who has been the subject of an espionage investigation in this office.

DateName

January 22, 1946

"News Bulletin" of the League for Industrial  
Democracy  
112 East 19th Street

Greenwich Village Director of the Civilian Rights  
Congress

American Russian Institute

Bombay Chlorine Products, Ltd.  
20 Peoples Building  
Bombay, India

~~M. GERSON~~  
131 Chester Hall,  
Oak Ridge, Tennessee

In connection with the above correspondent it was ascertained from the Knoxville Office that one MILLICENT GERSON, believed to be identical with the above addressor, is employed at the Nuclear Engine Propulsion Air Craft Division, Fairchild, Corporation, Oak Ridge, Tennessee as an Associate Physicist, and that GERSON has frequent access to secret and confidential material. GERSON was born on May 24, 1925 and resides at 64-34 99th Street, Forest Hills, Long Island. (u)

Confidential Informant T-1 has advised that OSCAR VAGO, BROTHMAN'S partner, was in contact with ROY JOHNSON at which time JOHNSON stated that he had been ordered in camp, believed to be an Army camp, learning riot control (u)

Classified by 2355 WAB/DOV  
Exempt from GDS, Category 2 & 3  
Date of Declassification Indefinite

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and how to break strikes. JOHNSON stated that he had sent this information to the right people. WAGO remarked that JOHNSON was right. The boys were learning riot control in camps. The New York Indices indicated that one ROY JOHNSON was a signer of a Communist Party Nominating Petition in 1942. His address at that time was 1522 Pacific Street, Brooklyn, New York. It is not known whether this individual is identical with the JOHNSON mentioned above by the informant. (u)

Reference is made to the letter to the Bureau dated July 11, 1947 in the case entitled "GREGORY, ESPIONAGE - R". It will be noted that this letter sets forth the facts pertaining to a complaint made by BROTHMAN concerning the agents who interviewed BROTHMAN. He charged that he was questioned regarding his activities in the interests of the Jewish Agency, which, in fact, was not true. BROTHMAN was represented in this matter by NACHIN BERNSTEIN, attorney, 20 Pine Street, New York City. After proper inquiries were conducted concerning this charge, Mr. BERNSTEIN advised that he was now of the opinion that he had been misled by BROTHMAN, and was regarding the incident as closed. The above is being set forth for any further contemplated contact with BROTHMAN. (u)

Reference is made to Bureau letter dated June 22, 1948 advising that a Security Index Card had been prepared on the subject. (u) b1

Confidential Informant T-10, of known reliability, advised of the



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From the information furnished above it would appear that ABRAHAM BROTHMAN is identical with the individual referred to above as [redacted] inasmuch as it is known that he maintained a laboratory or office at 114 East 32nd Street, and had a contract with both the Graver Tank Manufacturing Company and the Bridgeport Brass Company. (TS) b1

It is also known that BROTHMAN had been working for Mr. THEODORE HEILIG who is the President of the Regal Chemical Corporation, 115 Dobbin Street, Brooklyn. BROTHMAN, it will be noted, handled mathematical equations and processes concerning IDT work at the Regal Chemical Corporation for the United States Army. It will be noted that BROTHMAN assisted in this work with one ARTHUR P. WEBBER who was formerly a protege of BROTHMAN, having worked with him at the Hendrick Manufacturing Company and the Chemurgy Design Corporation, he being the secretary to the latter. (u)

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(S) (TS) It would appear that the individual by the name of [REDACTED] It will also be noted that an investigation has been previously conducted entitled, "REGAL CHEMICAL CORPORATION, THE REGAL CHEMICAL CORPORATION, THEODORE HEILIG, FRAUD AGAINST THE GOVERNMENT." (S) u

It will be noted that in the above investigation, WEBER gave a statement against HEILIG and is believed to have broken off his association with BROTHMAN as a result of differences that arose between them. WEBER was not indicted in this investigation; however, HEILIG was indicted. (u)

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LEADS

NEW YORK OFFICE

At New York City, New York

Will ascertain the subject's present Communist activities. (u)

Will develop the contacts of the subject during the period of 1940 through 1945 when the subject was employed by the Hendrick Manufacturing Company and the Chemurgy Design Corporation, and, in this connection, will consider interviewing ARTHUR P. WEBBER, a former close associate of the subject during that particular period who has apparently severed his relations with the subject as set forth in the Administrative Sheet of this report. (u)

\* \* \* \* \*

Two copies of this report are being submitted to the Washington Field Office in view of the fact that Washington Field Office is the office of origin in the Gregory Case in which BROTHMAN was also a subject. (u)

~~TOP SECRET~~

~~TOP SECRET~~

NY 100-95068

CONFIDENTIAL INFORMANTS

The Confidential Informants referred to in the report of SA FRANK J. GALLANT, dated September 19, 1949, at New York, are identified as follows:

T-1

[REDACTED] b2 b7D

T-2

Anonymous source

T-3

[REDACTED] b2 b7D

T-4

[REDACTED]

T-5

[REDACTED] (C) b1

T-6

[REDACTED] in the report of SA JEROME W. BROWER in the case entitled, "JULES KORCHIEN" dated June 11, 1945 at New York. b2 b7D

T-7

Anonymous source in the above report.

T-8

Anonymous source in the above report.

T-9

Anonymous source in the above report. b1

✓ T-10

[REDACTED]

(S)

~~TOP SECRET~~

~~TOP SECRET~~



100-365040-1

32114

SAC, New York

October 10, 1949

Director, FBI

ABRAHAM BROTHMAN  
SECURITY MATTER - C  
(New file 100-95065)

Burep of SA Francis J. Gallant dated September 29, 1949 (u)

Since Brothman is the subject of a Security Index card the Bureau desires to furnish copies of reports concerning him to the Department of Justice. (u)

The Bureau does not consider that you have sufficiently concealed the identity of Confidential Informants T-1, T-3 and T-5 in reference report. It is felt that the continued use of the words "contacted" and "phonetic" tend to expose the identities of the informants. (u)

Your attention is directed to paragraph 4 on page 10 of reference report. This paragraph which mentions a Department of Justice employee should not be included in the Investigative section of the report. (u)

It is requested that in your next report you include a summary of the pertinent information reflected in reference report with the informants' identities protected, so that a copy of the report can be furnished to the Department of Justice. (u)

A detailed description of subject should also be included in your report. (u)

COMMUNICATIONS SECTION  
MAILED 19  
OCT 11 1949 P.M.  
★  
FEDERAL BUREAU OF INVESTIGATION  
U. S. DEPARTMENT OF JUSTICE

ALL INFORMATION CONTAINED  
HEREIN IS UNCLASSIFIED  
DATE 11/19/87 BY 2142 RUC/bm

- Mr. Tolson
- Mr. Clegg
- Mr. Glavin
- Mr. Ladd
- Mr. Nichols
- Mr. Rosen
- Mr. Tracy
- Mr. Egan
- Mr. Gurnea
- Mr. Harbo
- Mr. Mohr
- Mr. Pennington
- Mr. Quinn Tamm
- Tele. Room
- Mr. Nease
- Miss Gandy

PCZ:dm;mce

NOV 30 1949

RECEIVED READING ROOM  
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OCT 18 3 27 PM '49  
U. S. DEPT. OF JUSTICE



# Office Memorandum • UNITED STATES GOVERNMENT

TO : The Director

DATE: February 6, 1950

FROM : D. M. Ladd

SUBJECT: ABRAHAM BROTHMAN  
SECURITY MATTER - C

Mr. Tolson  
Mr. E. A. Tamm  
Mr. Clegg  
Mr. Glavin  
Mr. Ladd  
Mr. Nichols  
Mr. Rosen  
Mr. Tracy  
Mr. Carson  
Mr. Egan  
Mr. Gurnea  
Mr. Harbo  
Mr. Hendon  
Mr. Pennington  
Mr. Quinn Tamm  
Tele. Room  
Mr. Nease  
Miss Gandy

## Background

Abraham Brothman was born August 15, 1913, in New York City. He attended schools in New York City and graduated from Columbia University with a Chemical Engineering Degree. He presently conducts his own engineering business in Long Island City, New York, under the name Abraham Brothman and Associates. (u)

## Investigation of Brothman

The Bureau first conducted an investigation on Abraham Brothman when we received information from Elizabeth Terrill Bentley in November, 1945. This was an espionage investigation. Miss Bentley advised that in approximately May of 1940, Jacob Golos, a known Soviet agent, introduced her to Abe Brothman who at that time resided in Nassau County, New York, and was employed as an engineer in the Republic Steel Company, New York City. Afterwards, Brothman indicated that he had some blueprints to be copied and Bentley delivered the blueprints to Golos. Miss Bentley advised that she met Brothman approximately ten times until some time in the Fall of 1940. She related that sometimes Golos would meet Brothman to obtain these blueprints direct, but whenever these appointments could not be handled personally, she would execute same. Miss Bentley was unable to state how many separate blueprints were actually delivered since they were supplied in an envelope. She recalled that on some occasions copies of the blueprints were delivered to her by Brothman. However, on other occasions it was necessary for her to take the originals and have copies made, which were thereafter delivered to Golos. The original would be returned to Brothman at a later time. Some time during these happenings, Miss Bentley learned that these blueprints were of commercial kettels which were understood to be some type of commercial vat. In the Fall of 1940, Golos indicated to Miss Bentley that he was somewhat discouraged with his dealings with Brothman and indicated that he was going to turn him over for handling to someone else. Miss Bentley did not learn from Golos or anyone else to whom Brothman was then directed. (u)

## Results of Investigation

The investigation indicated that Brothman associates with known Communists and also has solicited business from the Russian Government. He has been engaged

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52 FEB 13 1950

100-365040-2  
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DATE 3/19/87 BY 3042 RLB/clm

Memorandum to the Director

in engineering work for the Chinese Government and the development of a plant in Palestine. Confidential sources have furnished information which indicates that Brothman's secretary is a known Communist Party member and that Brothman frequently associates with Communists or individuals alleged to be engaged in espionage. (u)

On May 29, 1947, Brothman was interviewed by FBI Agents. He advised that he had furnished blueprints to a number of individuals as it is a common practice in the engineering field to submit blueprints to persons who may be in a position to obtain contracts for a firm. After identifying a photograph of Miss Bentley, he finally identified Jacob Golos from his photograph, although he could not remember him by name. Brothman alleged that he furnished the blueprints to Golos and to Miss Bentley, who he thought was Golos' secretary, because Golos had advised him that he had contacts with the Russian Government and could procure contracts for Brothman. He said the blueprints were of shafts, vats, filters, and other machinery used in the manufacture of chemicals. He denied ever furnishing any blueprints which were of a restricted or secret nature pertaining to the war effort. He further stated that he had submitted various contracts to the Amtorg Trading Company and the Soviet Government Purchasing Commission, but had never obtained a single contract. (u)

Brothman admitted that he had been a member of the Young Communist League in 1933 while at Columbia University, but that he presently attended no Communist Party meetings or engaged in any Communist Party activities. (u)

Prosecutive Action

On July 22, 1947, Brothman testified before a Special New York Federal Grand Jury sitting in the Southern District of New York, which was considering the allegations of Elizabeth Bentley. (u)

Distribution

The distribution appears on the attached paper. (u)

Status

Investigation of Brothman is continuing. (u)

Attachment

*This must be vigorously  
pressed.*  
H.

DISSEMINATION

White House

Summary entitled, "Underground Soviet Espionage Organization (NKVD) in Agencies of the United States Government" dated February 21, 1946.

Summary entitled, "Soviet Activities in the United States" dated July 25, 1946.

Summary entitled, "Underground Soviet Espionage Organization (NKVD) in Agencies of the United States Government" dated October 21, 1946.

Attorney General

Summary entitled, "Underground Soviet Espionage Organization (NKVD) in Agencies of the United States Government" dated February 21, 1946.

Summary entitled, "Soviet Activities in the United States" dated July 25, 1946.

Summary entitled, "Underground Soviet Espionage Organization (NKVD) in Agencies of the United States Government" dated October 21, 1946.

To Whom Furnished and Date

Brigadier General Harry H. Vaughan, Military Aide to the President.  
2/25/46 (65-56402-573)

Attorney General on 7/25/46 for the use of the President in connection with the Paris Conference on  
7/29/46 (100-345686-1)

George Allen, Presidential Advisor.  
12/16/46 (65-56402-1817)

To Whom Furnished and Date

Attorney General  
2/25/46 (65-56402-573)

Attorney General  
7/25/46 (100-345686-1)

Attorney General on 11/27/46; an additional copy on 12/2/46.  
(65-56402-1754-1756)

A. Devitt Vanech, Special Assistant to the Attorney General.  
12/6/46 (65-56402-1837)

T. Vincent Quinn, Assistant Attorney General. Two copies on 7/23/47, an additional copy on 8/7/47.  
(65-56402-2693-2727)

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100-365040-2



State Department

Summary entitled, "Underground Soviet Espionage Organization (NKVD) in Agencies of the United States Government" dated February 21, 1946.

Summary entitled, "Underground Soviet Espionage Organization (NKVD) in Agencies of the United States Government" dated October 21, 1946.

Treasury Department

Summary entitled, "Underground Soviet Espionage Organization (NKVD) in Agencies of the United States Government" dated February 21, 1946.

Summary entitled, "Underground Soviet Espionage Organization (NKVD) in Agencies of the United States Government" dated October 21, 1946.

War Department

Summary entitled, "Underground Soviet Espionage Organization (NKVD) in Agencies of the United States Government" dated February 21, 1946.

Central Intelligence Group

Summary entitled, "Underground Soviet Espionage Organization (NKVD) in Agencies of the United States Government" dated February 21, 1946.

Navy Department

Summary entitled, "Underground Soviet Espionage Organization (NKVD) in Agencies of the United States Government" dated February 21, 1946.

To Whom Furnished and Date

Secretary of State.  
2/25/46 (65-56402-573)

Mr. Frederick B. Lyon, Chief,  
Division of Foreign Activity  
Correlation, State Department.  
3/13/46 (65-56402-616)

Secretary of State.  
11/25/46 (65-56402-1836)

Mr. Frederick B. Lyon, Chief,  
Division of Foreign Activity  
Correlation, State Department.  
12/12/46 (65-56402-1859)

To Whom Furnished and Date

Secretary of Treasury.  
3/4/46 (65-56402-529)

T. Vincent Quinn, Assistant  
Attorney General, on 3/6/48  
for Ed Foley, Treasury De-  
partment.  
(65-56402-3148)

To Whom Furnished and Date

Lieutenant General Hoyt S.  
Vandenberg, Assistant Chief  
of Staff, G-2, War Department.  
3/7/46 (100-3-1313)

To Whom Furnished and Date

Admiral Sidney W. Souers,  
Central Intelligence Group.  
4/2/46 (65-56402-725)

To Whom Furnished and Date

Admiral William D. Leahy,  
Chief of Staff to the  
Commander in Chief, Army and  
Navy, White House.  
3/13/46 (65-56402-655)

# Office Memo

UNITED STATES GOVERNMENT

TO : Director, FBI

DATE: April 6, 1950

FROM : SAC, New York

SUBJECT: ABRAHAM BROTHMAN  
SECURITY MATTER - C

14275

TOP SECRET

Re: Rep of SA John E. Murphy, Jr., 4/5/50, New York, in captioned case and the report of SA Carlton G. Lenz in the case, "UNSUB, Was. [REDACTED] - ESPIONAGE - R."

In addition to the leads set out in the report of SA Murphy, the Newark Office is requested to identify by indices, credit checks and, if necessary, discreet neighborhood inquiry, contacts of BROTHMAN who reside in the Newark Office territory:

Joseph Taylor  
3444 Gregory Street  
Passaic, New Jersey

F. J. Coffey  
100 North 3rd Street  
Metuchen, New Jersey

E. Gelb  
86 West Alpine Street  
Newark, New Jersey

H. F. Stevens  
674 Woodland Avenue  
Kenilworth, New Jersey

Dr. J. W. Pinck  
142 Paulison Avenue  
Passaic, New Jersey

W. M. Smith  
744 Broad Street  
Newark, New Jersey

Jerome Klein  
1446 Ormond Avenue  
Camden, New Jersey

Charles Mark  
1104 Washington Street  
Hoboken, New Jersey

S. E. Matlin  
108 West 42nd Street  
Bayonne, New Jersey

S. Petruzella  
606 Downer Street  
Westfield, New Jersey (u)

It is requested further that these identifications be reported in captioned case. (u)

cc - Newark

JEM:IM  
100-95068

Classified by 312 POT/clm  
Declassify at: OADR

INDEXED - 85 APR 7 1950

Classified by 2335 WAB/DMN  
Exempt from GDS. Category 2-3  
Date of Declassification: [REDACTED]

58 JUN 5 1950

TOP SECRET

ADMIN. CE

APR 1 1950  
FBI OFFICES  
ADMIN. & RECORDS  
SLIP(S) OF Classification

100-365040-3  
APR 7 1950  
EX-62  
EVE  
OK 1/5/51

FD-72  
(1-10-49)

FEDERAL BUREAU OF INVESTIGATION

Mr. Tolson \_\_\_\_\_  
Mr. Ladd \_\_\_\_\_  
Mr. Clegg \_\_\_\_\_  
Mr. Glavin \_\_\_\_\_  
Mr. Nichols \_\_\_\_\_  
Mr. Rosen \_\_\_\_\_  
Mr. Tracy \_\_\_\_\_  
Mr. Harbo \_\_\_\_\_  
Mr. Egan \_\_\_\_\_  
Mr. Mohr \_\_\_\_\_  
Tele. Room \_\_\_\_\_  
Mr. Nease \_\_\_\_\_  
Miss Gandy \_\_\_\_\_

Form No. 1

THIS CASE ORIGINATED AT

NEW YORK

~~TOP SECRET~~

FILE NO.

100-35040-3

REPORT MADE AT

NEW YORK

DATE WHEN MADE

4/5/50

PERIOD FOR WHICH MADE

2/16-24, 26, 27;  
3/21-23/50

REPORT MADE BY

JOHN R. MURPHY, JR.

TITLE

~~TOP SECRET~~

ABRAHAM BROTHMAN

aka. Abc Brothman

SECURITY MATTER -

014276

SYNOPSIS OF FACTS:

Classified by 355 WAB/AVM  
Exempt from GDS, Category 293  
Date of Declassification Indefinite

~~CONFIDENTIAL~~ WAB/AVM  
ADMINISTRATIVE 10-1-75, P-1

3/19/87  
Classified by 355 WAB/AVM  
Declassify on: OADR

A review of BROTHMAN'S activities from November, 1945 to May, 1947 made in an effort to establish identities of all of his contacts on the possibility that one of them is the unknown subject. Identification of some of these contacts made. BROTHMAN currently operates A. Brothman & Associates, Chemical Engineers, Long Island City, NY and resides at 4108 42nd St., Sunnyside, Long Island. Current surveillance photograph obtained, results of additional confidential sources obtained and set forth. Leads set out.

DETAILS:

Confidential Informant T-1, of known reliability, reported

APPROVED AND FORWARDED

SPECIAL AGENT IN CHARGE

ENCLOSURE

DO NOT WRITE IN THESE SPACES

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- 5 - Bureau
- 2 - Boston
- 2 - Chicago
- 2 - Newark
- 1 - Philadelphia (Info)
- 1 - Washington Field (Info)
- 4 - New York (1 NY 65-15136)

~~TOP SECRET~~

PROPERTY OF FBI - This confidential report and its contents are loaned to you by the FBI and are not to be distributed outside of agency to which loaned.



NY 100-95068

Since it has been further ascertained from T-1 that [REDACTED]

~~TOP SECRET~~

BROTHMAN'S ACTIVITIES FROM NOVEMBER 28, 1945 TO MAY 29, 1947

December 5, 1945

Confidential Informant T-2, of known reliability, advised that MIRIAM MOSKOWITZ, BROTHMAN'S secretary, informed him on that date that Dr. BERGMAN wanted to see BROTHMAN in the near future. She stated that she would arrange an appointment for BROTHMAN to see Dr. BERGMAN. She also mentioned that NANAVATI, apparently a native of India, would be leaving New York on December 6, 1945. (u)

T-2 advised that MARION MOSKOWITZ contacted Dr. BERGMAN who stated that he could see BROTHMAN on December 8 or December 9, 1945. BERGMAN also asked that BROTHMAN meet with him and an engineer from Palestine. BERGMAN indicated that he would be in New York only during the weekend; that his laboratory is in Philadelphia. Later, on the same date, a definite appointment was made by MOSKOWITZ for BROTHMAN to see BERGMAN at 4:30 P.M. on December 8. (u)

December 6, 1945

1. Mr. MICHEL, Hotel Madison Square, New York City, asked for an appointment to see BROTHMAN in the near future. (u)

December 7, 1945

A Mr. SHURA made an unsuccessful attempt for an appointment to see BROTHMAN on this date. (u)

T-2 further advised that on the same date, MOSKOWITZ told OSCAR VILGO, a partner of BROTHMAN, that BROTHMAN has some material which he is anxious to discuss with R. M. NANAVATI, Shoreham Hotel, Washington, D. C., before NANAVATI leaves for Bombay, India. (u)

100-365040-3

NY 100-95068

December 8, 1945

T-2 advised that BROTHMAN made an unsuccessful attempt to contact NANAVATI at the Shoreham Hotel, Washington, D. C. T-2 advised that BROTHMAN determined from the St. Regis Hotel, New York City, that NANAVATI'S mail was to be addressed to MAX VAN PELS, 441 Lexington Avenue, New York City. BROTHMAN also indicated on this date that he had to see Dr. BERGMAN at 4:00 P.M. (u)

December 10, 1945

MOSKOWITZ informed BROTHMAN that EDWARD JACOBS, Ordinance Instrument Company, wanted BROTHMAN to contact him. MOSKOWITZ informed BROTHMAN that LOU BERNE (ph) had contacted him. (u)

December 11, 1945

MOSKOWITZ asked VAGO to contact JACOBS and arrange a luncheon appointment for BROTHMAN at the Vanderbilt Hotel for that date at 1:00 P.M. However, MOSKOWITZ indicated that BROTHMAN did not know JACOBS. She indicated that JACOBS' telephone number is MU 2-6803. (u)

On the same date, a Mr. FRISCHER attempted unsuccessfully to contact BROTHMAN. (u)

BROTHMAN contacted a Mr. C. S. SWAN concerning BROTHMAN'S new process. T-2 also advised that one CY SILVERSTEIN is one of BROTHMAN'S employees at his laboratory. (u)

December 12, 1945

MOSKOWITZ informed BROTHMAN that he had a "letter from his friend" who would be at BROTHMAN'S office at about 12:45 P.M. that date. BROTHMAN indicated further that he would have luncheon with FRISCHER on that date. (u)

A physical surveillance of BROTHMAN on December 12, 1945 reflected that at 1:40 P.M. he left his office at 114 East 32nd Street with an unidentified man described as 5' 8", 150 pounds, about 60 years of age, gray hair, wearing a black hat and black overcoat. They proceeded to the Vanderbilt Hotel and the unidentified man was not seen leaving the hotel with BROTHMAN. (u)

T-2 stated that a Mr. DEUTSCH, an engineer, contacted BROTHMAN and had a long technical discussion with BROTHMAN. DEUTSCH is the individual who sent NANAVATI to BROTHMAN for professional assistance. He indicated that he was going to India the following week. BROTHMAN indicated to DEUTSCH that his firm had been working on a project for the Chinese Government. (u)

NY 100-95068

T-2 advised that BROTHMAN contacted one ~~GONZALES~~ with whom BROTHMAN discussed the construction of a plant to make D.D.T. GONZALES made an appointment to see BROTHMAN on the following day at BROTHMAN'S office. (u)

T-2 advised that one ~~CYMANDELKORN~~ (ph) apparently was an employee of BROTHMAN on that date. (u)

BROTHMAN contacted BERNIE ~~PIDTO~~ on a business matter. (u)

December 13, 1945

MOSKOWITZ made reservations for PIDTO to travel to Washington on December 17, 1945, apparently on behalf of BROTHMAN. (u)

December 14, 1945

~~X~~OAS (ph) MOSKOWITZ contacted the Army Base and inquired for Lieutenant who had left his office for the Finance Section of the Army Base. (u)

On the same date, T-2 stated that Lieutenant OAS contacted MOSKOWITZ and inquired whether she needed his signature for anything. She stated that she did not. (u)

*Inducing* T-2 stated that BROTHMAN had a technical discussion with one Dr. ~~ROSENSTEIN~~. (u)

December 15, 1945

T-2 advised that SEYMOUR ~~MANDELKORN~~, an employee of BROTHMAN, was residing at 67 Jane Street, Apartment 3B, New York as of that date. T-2 also advised that one ~~WILPERN~~ was an employee of BROTHMAN. (u)

December 16, 1945

T-2 advised that BROTHMAN contacted R. V. ~~MICHEL~~, Sales Promotion Director, Union Chimique Belege, 61 Avenue Louise, Brussels, Belgium, concerning some work that BROTHMAN had been doing for MICHEL. MICHEL indicated that he would be leaving New York on the following day for Belgium. (u)

December 18, 1945

T-2 advised that BROTHMAN contacted the Resinous Products and Chemical Company, Philadelphia, concerning some technical matters. (u)



NY 100-95068

T-2 advised that BROTHMAN later contacted a Dr. ROSENSTEIN. BROTHMAN indicated that he wanted to show ROSENSTEIN some material he had developed in his laboratory for the Chinese Government. BROTHMAN mentioned a young fellow, EMANUEL GREEN, recently discharged from the Army, a friend of his, who was looking for a position as an operator in a plant. ROSENSTEIN promised to do what he could for GREEN. (u)

December 20, 1945

T-2 advised that BROTHMAN contacted a Dr. ROSENSTEIN who, according to the informant, then had telephone number MU 5-2466. (u)

A Mr. STEIGLE (ph) of the American-Russian Institute, New York contacted BROTHMAN stating that he understood BROTHMAN knows what the Russians are doing in the field of chemistry and wanted to interview BROTHMAN on behalf of the American-Russian Institute. An appointment was made by STEIGLE to see BROTHMAN in BROTHMAN'S office on the following day. (u)

T-2 stated that one JACKSON, to whom BROTHMAN appeared very friendly, contacted BROTHMAN during which conversation BROTHMAN indicated he was progressing satisfactorily on the contract for the Chinese Government. JACKSON invited BROTHMAN to a New Year's Eve party which invitation BROTHMAN accepted. (u)

December 21, 1945

BROTHMAN contacted a Dr. BLUMENFELD with whom he had a discussion on a chemistry report. (u)

December 24, 1945

T-2 stated that BROTHMAN contacted his wife and indicated that he had had lunch on that date with Dr. BLUMENFELD. He further indicated that he would have another conversation with Dr. BLUMENFELD on December 25, 1945 as well as with Dr. WEIZMAN who was staying at the Essex House, New York City. (u)

December 25, 1945

T-2 advised that Dr. BLUMENFELD asked that BROTHMAN meet him at his home, 322 West 22nd Street, at 3:00 P.M. on that date to which BROTHMAN agreed. (u)

Later on the same date, BROTHMAN indicated to his wife that BLUMENFELD'S full name was Dr. JOSEPH BLUMENFELD. (u)

NY 100-95068

December 26, 1945

MOSKOWITZ ascertained from an unidentified woman that EMANUEL GREEN'S Chicago address is 7853 Essex Street, Chicago, Illinois. (u)

December 27, 1945

Dr. BERGMAN'S secretary informed MOSKOWITZ that BERGMAN had an appointment to see BROTHMAN at 9:00 P.M. on December 28, 1945 at the Russian Tea Room, New York City but that BERGMAN desired the appointment be changed to 10:00 P.M. (u)

T-2 advised that one ALEX WEBER, telephone number Berclay 7-6348, attempted unsuccessfully to contact BROTHMAN. (u)

December 28, 1945

T-2 stated that a man named MILLER invited BROTHMAN and his wife to a party at MILLER'S house the following Monday night. (u)

December 31, 1945

ALEX WEBER again attempted unsuccessfully to contact BROTHMAN. (u)

January 3, 1946

T-2 advised that JACK MILLER contacted BROTHMAN and indicated that he would see BROTHMAN later in the day. (u)

BROTHMAN contacted Dr. BLUMENFELD who informed him that Dr. BERGMAN would be in BLUMENFELD'S office that afternoon. BROTHMAN agreed to come over to BLUMENFELD'S office. (u)

LEO LITTLEMAN contacted BROTHMAN on a business matter. (u)

Mr. HILL, who, according to T-2, has some connection with contracts with the Chinese Government, asked that BROTHMAN come to his office, Room 310, 610 Fifth Avenue at 3:30 P.M. on January 4, 1946 to which BROTHMAN agreed. (u)

MIRIAM MOSKOWITZ made a hotel reservation at a hotel apparently operated by FRED BRIEHL, Wallkill, New York for three adults and one child. She indicated that they would arrive on the following Sunday. (u)

NY 100-95068

January 4, 1946

A Mr. GERARD ~~X~~PIEL (ph) ~~X~~Kaiser Company, Room 310, 620 Fifth Avenue, contacted MOSKOWITZ requesting that he be furnished with BROTHMAN'S bibliography. (u)

T-2 stated that BROTHMAN attempted unsuccessfully to contact JACK MILLER. (u)

A Mr. ~~X~~SPRINGER, Eldorado 5-1123, attempted unsuccessfully to contact BROTHMAN. (u)

HARRY ~~X~~SLAVIN conferred with BROTHMAN advising that Dr. BERGMAN would be leaving for London in the immediate future. (u)

BROTHMAN contacted JACK MILLER whom he informed that he had contacted "that ~~X~~Bozo" and had an appointment with him. BROTHMAN indicated that he would give MILLER a build up and that possibly this individual would have use for MILLER. (u)

T-2 stated that an unidentified male contacted MOSKOWITZ and stated that PIEL (ph) apparently was impressed with BROTHMAN and that Kaizer would undoubtedly have a place for BROTHMAN. (u)

January 16, 1946

MIRIAM MOSKOWITZ advised VAGO that BROTHMAN would be at Wallkill, New York for the rest of the week. (u)

January 2, 1946

JACK MILLER contacted BROTHMAN. BROTHMAN told MOSKOWITZ that he had wanted to tell him about the meeting in Kaizer's office. MILLER apparently had told the Kaizer people about BROTHMAN and apparently they are interested in something BROTHMAN has. (u)

On the same date, an unidentified man contacted BROTHMAN stating that he is now located in Brooklyn where he operates a business. The man indicated that he was thinking of moving to 114 32nd Street, New York City where BROTHMAN is and wanted to know if that was a professional building. BROTHMAN stated that it was not exactly but that there were laboratories in the building, thus indicating the possibility that the unidentified man operates a laboratory. This man made an appointment to see BROTHMAN at BROTHMAN'S office at noon the following Friday. (u)



NY 100-95068

January 22, 1946

HARRY SLAVIN made an appointment to see BROTHMAN at 4:00 P.M. on that date. (u)

A Mr. ~~X~~KAHN, who indicated that he was then in the presence of HARRY SLAVIN, stated that he was connected with the Consolidated Products Company. He made an appointment to see BROTHMAN in BROTHMAN'S office with SLAVIN on that date. (u)

February 2, 1946

BROTHMAN informed his wife that he had to meet ~~X~~FRANK that evening before coming home and would be home as soon as possible. (u)

February 4, 1946

T-2 stated that BROTHMAN contacted Mr. ~~X~~BOWEN of the Bowen Engineering Company, Garwood, New Jersey. BROTHMAN indicated that he is developing some resins for the Chinese Government. (u)

BROTHMAN contacted a Mr. ~~X~~OLIVE at the McGraw Hill Publishers stating that he wanted to arrange a luncheon with OLIVE to discuss the possibility of purchasing some articles on the work he has been doing in the chemical field. (u)

On the same date, T-2 advised that LUDWIG ~~X~~MUSET (ph) conferred with BROTHMAN who advised MUSET that he feels he had developed Polymerization that could be patented. He discussed the possibility of having luncheon together during the following week. (u)

February 7, 1946

BERNARD ~~X~~KOOPMAN, a teacher at Columbia University, made a tentative date to see BROTHMAN the following Wednesday. (u)

February 13, 1946

KOOPMAN again contacted BROTHMAN and BROTHMAN arranged to meet him at the King's Crown Hotel near Columbia University. KOOPMAN mentioned having received a letter in Washington from BROTHMAN in the recent past. (u)

February 18, 1946

KOOPMAN advised BROTHMAN that he had broken down the differential equation problem and was ready to show it to BROTHMAN. They made an appointment to see each other that evening. (u)

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February 21, 1946

A woman, probably identical with ~~URSULA~~ WASSERMAN, contacted BROTHMAN stating that she was leaving the United States the following Wednesday on a Norwegian boat. She stated that the boat stops at Trinidad and then at Buenos Aires. She said that she was worried about what she would do about the "subversive papers." BROTHMAN said they would cope that out later and they agreed to meet that evening for dinner. (u)

March 4, 1946

BROTHMAN contacted a ~~ROBERT~~ TUCKER, Hoboken, New Jersey regarding some specifications on some materials. (u)

March 5, 1946

LEO MITTELMAN, telephone number Worth 2-3100, made an unsuccessful attempt to contact ~~JULES~~ KORCHEIN in BROTHMAN'S office. (u)

~~JACK~~ MILLER cancelled a luncheon date with BROTHMAN for this date stating that he would try to see BROTHMAN at BROTHMAN'S office later in the afternoon. (u)

March 8, 1946

MOSKOWITZ made reservations on American Airlines for March 12, 1946, Flight 236 for Boston and on return Flight 233 leaving Boston at 8:10 P.M. March 13, 1946. (u)

March 11, 1946

~~GERARD~~ PIEL (ph), telephone number Circle 6-4725 and Circle 6-5343, made an unsuccessful attempt to contact BROTHMAN. (u)

March 13, 1946

A Mr. ~~EARL~~, an engineer in Cambridge, Massachusetts, contacted BROTHMAN. BROTHMAN indicated he would be going to Cambridge the following day at 2:30 P.M. and would confer with ~~EARL~~ and other technicians. (u)

March 25, 1946

HARRY SLAVIN attempted to contact BROTHMAN on two occasions on that date indicating that he had to see BROTHMAN on urgent business. (u)

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✓ GERARD PIEL (ph) contacted BROTHMAN regarding the possible contract for plastic windshields to be used in making small automobiles at Bristol, Pennsylvania. (u)

Between April 1 and April 30, 1946, T-2 advised that BROTHMAN made two trips; one to Buffalo and one to Washington, D. C. where, according to the informant, he contacted employees of Kaizer-Frazer Corporation in regard to his possible employment by the organization. T-2 also reported that BROTHMAN had made a study for EDGAR KAIZER and had left this material with KAIZER at the time he had seen him in Washington, D. C. (u)

X On April 23, 1946, MIRIAM MOSKOWITZ attempted to make reservations for a trip on May 11 or 12, 1946 on American Airlines but no space could be given her. (u)

During the period from May 1 to June 5, 1946, T-2 advised that a Mr. LECATUR (ph) was in contact with BROTHMAN advising him that he had a letter from the Soviet Union addressed to a Mr. POWELL. According to LECATUR, the letter confirmed what he and BROTHMAN discussed at the meeting and had also itemized a few things that the Soviet Union wants. LECATUR also wanted to know how BROTHMAN was making out on "that proposal" and BROTHMAN indicated that he had someone work on it, that it would be ready by the end of the following week. LECATUR added that POWELL wanted to sit in with BROTHMAN after a draft is made of the proposal and before it is typed. LECATUR stated that POWELL is in Boston a great deal of the time. BROTHMAN then made the statement that he was getting up a description of his plastics for LECATUR and would make three copies of this description for the Russians. LECATUR stated that he would mail BROTHMAN a photostatic copy of the letter he had received from the Soviet Union. (u)

On May 8, 1946, T-2 stated that BROTHMAN apparently had made an application for credit on American Airlines. This credit was to be extended all over the United States. (u)

On May 15, 1946, ROSE REUBEN of the American-Russian Institute had a conference with BROTHMAN, at which time she asked him if he could suggest or recommend someone who knew technical Russian. She stated that the American-Russian Institute issued a pamphlet describing the technical phases of Soviet industries and that they needed a person to translate from the Russian into English. BROTHMAN suggested that names: M. THOMAS, 48th Street, Sunnyside Long Island; SHIRAZ SWAN, no address; and an employee of his laboratory, BILL ROHALL, Queeduct Avenue, Bronx, New York who had been used as a translator of Russian. REUBEN indicated that she knew SWAN since he had been used as a translator for Technical Commission and had come to the United States from Russia. (u)



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On June 3, 1946, T-2 stated that BROTHMAN had been in the upper part of New York State for the weekend and that he was working on some job for Amtorg. (u)

On June 18, 1946, T-2 indicated that BROTHMAN was in contact with CY MANDELKORN and SOL FANSHEL, apparently employees of BROTHMAN. They mentioned that HARRY SILVIN, 510 West 172nd Street, New York City, had had some discussion with BROTHMAN prior to this conversation. (u)

On June 7, 1946, LECATUR (ph) endeavored to get in touch with BROTHMAN who was not available. He spoke to VAGO, BROTHMAN'S associate, who told him that the meeting with POWELL was off but that they would meet at a later time in BROTHMAN'S office to discuss the Soviet Russian proposal. (u)

T-2 advised that MOSKOWITZ made reservation for three persons to fly to Chicago on June 15, 1946 and to return to New York on June 16, 1946. (u)

On June 9, 1946, T-2 advised that KORCHEIN, BROTHMAN'S associate, was in touch with NEEDLEMAN of Amtorg. At that time KORCHEIN told NEEDLEMAN that he would like to have him meet ABRAHAM BROTHMAN inasmuch as BROTHMAN was involved in some work (apparently for the Russians) and that he wanted NEEDLEMAN to discuss this work with him. (u)

On June 10, 1946, T-2 advised that BROTHMAN attempted to contact E. N. GOSSELIN in Chicago, Illinois. Later, BROTHMAN contacted a Mr. SPRINGER and informed him that BROTHMAN had a contract with the Russians in which GOSSELIN possibly might be interested. (u)

On the same date, T-2 advised that BROTHMAN attempted to locate Mr. LECATUR (ph). In the absence of LECATUR, BROTHMAN spoke to a Mr. FLAGG and told him he was going to send some material to POWELL, 405 Park Square Building, Boston, Massachusetts. (u)

It is to be noted that on July 23, 1946, an unknown individual conferred with BROTHMAN requesting some figures regarding the production of plastics. This man told BROTHMAN that he had some Turks whom he wanted BROTHMAN to meet and who are interested in plastics. This man asked BROTHMAN if he had submitted his report on plastics to the Russians. BROTHMAN stated that he had. (u)

On September 13, 1946, T-2 reported that BROTHMAN was in contact with one Mr. RADIONOVICH (ph) at Amtorg who informed BROTHMAN that he was going back to Moscow and that his place would be taken by a Mr. MAICROV. RADIONOVICH

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stated that when he went to Moscow in October, he would take up the questions that BROTHMAN had requested of him and that he would send over the things which BROTHMAN had requested. However, at this time he had received no replies from Moscow. (U)

*Handwritten: Note re: material*  
On September 19, 1946, T-2 reported that MOSKOWITZ, BROTHMAN'S secretary, contacted the Du Pont Company, New York City asking if that firm can supply 12,000 pounds a month of "regular acrylic monama and copalama (ph)." The Du Pont people were very inquisitive as to what the material would be used for and MOSKOWITZ consulted an unknown person in BROTHMAN'S office after which she stated that it would be used for moldings. The Du Pont representative wanted to know whether the materials would be exported and she replied in the negative. The Du Pont people did not give any definite answer on the proposition. Immediately thereafter, MOSKOWITZ attempted to contact Mr. TATEONOVICH (ph) at Amtorg but was unsuccessful, giving rise to the possibility that the Russians, through BROTHMAN were attempting to obtain some materials. (U)

Confidential Informant T-3, of known reliability, has advised that as of June 28, 1946, BROTHMAN was doing business with VLADIMIR TVERIANOVICH, an engineer of the Fishing Industry Group of the Soviet Government Purchasing Commission, then connected with Amtorg, New York City. (U)

T-3 also advised that BROTHMAN was reportedly working on a vitamin plant for the Russians around that time. (U)

T-2 advised on October 24, 1946 that BROTHMAN had attempted unsuccessfully to contact JULIUS BRODY at Plaza 3-9533 or Plaza 3-9535. (U)

On October 28, 1946, BROTHMAN spoke to NEEDLEMAN at Amtorg. NEEDLEMAN stated that TVERIANOVICH had returned; that NEEDLEMAN had not spoken to him and will not until BROTHMAN has a chance to see him. (U)

On October 30, 1946, T-2 stated that NEEDLEMAN at Amtorg informed BROTHMAN that he had just talked to TVERIANOVICH and that "he knows all about it and has known all about it all the time but is under advice not to let on." NEEDLEMAN stated further that "thing" was sent over with TVERIANOVICH'S strongest recommendations. NEEDLEMAN further stated that TVERIANOVICH has said that he out to everyone else who attempts to contact him but that he was very anxious to make an appointment to say good-bye to BROTHMAN. (U)

On October 30, 1946, NEEDLEMAN informed BROTHMAN that TVERIANOVICH would be in New York for another two weeks. NEEDLEMAN stated that he would try to arrange something definite in the way of an appointment for BROTHMAN with

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TVERIANOVICH. However, the informant never reported subsequent discussions by BROTHMAN concerning a meeting with TVERIANOVICH and as far as it is known he never did meet him prior to the time TVERIANOVICH left the United States on December 23, 1946. (u)

On November 8, 1946, T-2 reported that BROTHMAN conferred with one ALBERT OSBORNE who asked that BROTHMAN act as a reference for OSBORNE and substantiate OSBORNE'S statements to future employers that he had worked for BROTHMAN from 1937 to 1940. BROTHMAN assured him that he would do so. He stated that he and several others had been dismissed by Celanese, Inc. in view of some union activity and that he does not want to use Celanese as a reference or as a former employer. He said that he had been referred to BROTHMAN by BEN SILVERMAN. (u)

On the same date, JACK MILLER contacted BROTHMAN and asked him if he knew what CAPITZA'S field in science was. BROTHMAN said that CAPITZA is a leading Russian physicist and that he understands that he has done revolutionary turbine. MILLER stated that he intended to go to Washington during the following week where he intended to see "the assistant to the Assistant Attorney General", to whom he referred to as "the last of the appendage." (u)

On December 2, 1946, BROTHMAN contacted a Mr. HAMLET of "Time" and "Life" stating that he had the "rough proposal" ready and would deliver it the following morning to the New York Athletic Club. HAMLET asked that BROTHMAN send it there or to 247 Park Avenue. (u)

On December 3, 1946, the secretary to LEO GOTTlieb advised BROTHMAN that GOTTlieb was having dinner that evening with POWELL and that they would like BROTHMAN'S memorandum that afternoon. (u)

On December 5, 1946, BROTHMAN made an appointment to meet a Mr. STRICKLER, telephone Sherwood 2-9778, Paterson, New Jersey. The meeting was set for the Hotel New Yorker at 6:30 P.M. (u)

On December 6, 1946, Mr. MISHKEN contacted BROTHMAN and informed him that LEVINE was leaving town about would return the following Wednesday and discuss in detail the points in the agreement and option. (u)

On December 7, 1946, T-2 stated that LEO GOTTlieb contacted BROTHMAN and informed him that he had BROTHMAN'S memorandum concerning the erection of a plant in China for the Chinese Government and wanted to meet with BROTHMAN about the matter. GOTTlieb furnished his phone number as Hanover 2-8989. (u)



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On December 13, 1946, T-2 stated that BROTHMAN made inquiry of the American-Russian Institute library to ascertain if they had the following publication on file: "Journal of General Chemistry--USSR", volume 11, pages 1111-1120. He was informed that this document is not on file at the American-Russian Institute. (u)

On December 16, 1946, H. LEVINE of the Commonwealth Plastics Corporation, Leominster, Massachusetts, contacted BROTHMAN and wanted to know if BROTHMAN could arrange a meeting for the Chinese Purchasing Commission which has indicated an interest in an operation in this country. LEVINE stated he was in favor of working out an arrangement whereby he and BROTHMAN would make a deal with the Chinese to manufacture certain raw materials for them at the "East Plant" or perhaps the Chinese would be interested in buying a half interest in the main plant. BROTHMAN was in favor of arranging a meeting with the Chinese and promised to advise LEVINE what time would be convenient for him. (u)

On December 19, 1946, H. LEVINE again contacted BROTHMAN and suggested that BROTHMAN visit the "East Plant" at York, Pennsylvania on the following Monday or Tuesday to survey its possibilities. BROTHMAN agreed to do so and stated he would contact Mr. LEWIS, General Manager of the plant. (u)

On December 21, 1946, BROTHMAN instructed OSCAR VAGO, one of his partners, to go to York, Pennsylvania to inspect the "East Plant" and to bring back freehand sketches of the plant in order to determine if BROTHMAN could use it. (u)

On December 23, 1946, BROTHMAN contacted H. LEVINE at Leominster, Massachusetts stating that he was arranging for a job with the Chinese Purchasing Commission for the manufacture of certain chemicals. (u)

On December 24, 1946, LEVINE informed BROTHMAN that the attempted deal with the Chinese Purchasing Commission had fallen through and that the Chinese wanted to go into the venture alone. (u)

In connection with another big business deal, BROTHMAN stated he was trying to contact BERGMAN in Philadelphia. LEVINE stated he would attempt to contact BERGMAN for BROTHMAN and advise BROTHMAN later. (u)

On December 26, 1946, T-2 stated that BROTHMAN agreed to meet Dr. BERGMAN at BERGMAN'S suite in the Hotel Salisbury, 123 West 57th Street on the evening of December 27, 1946. (u)

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On January 15, 1947, a Dr. ~~RUANI~~, 183 Brown Street, Providence, Rhode Island, contacted BROTHMAN explaining that he has a business contact in Switzerland who is anxious to have a connection in the manufacture of plastics. BROTHMAN authorized RUANI to contact this friend on his behalf. (u)

On January 22, 1947, Confidential Informant T-4, of known reliability, advised that a Mr. ~~KUNEN~~, possibly identical with Mr. JAMES ~~KUNEN~~ 40 West 40th Street, and a contact of JULES KORCHEIN, was endeavoring to make an appointment with BROTHMAN. (u)

T-4 reported on January 23, 1947 that BROTHMAN was in contact with a Mr. STRICKLER who advised that his Atlantic City telephone number was Shore 2-9778. (u)

Confidential Informant T-5, of known reliability, reported that STRICKLER is probably SIMON H. ~~STRICKLER~~ of Strickler and Company, 45 Church Street, Paterson, New Jersey. (u)

On January 24, 1947, LEO GOTTLIEB endeavored to contact BROTHMAN and furnished his phone number as Lambert 3-5833. (u)

On the same date, T-4 reported that EARL GILMAN conferred with SOL ~~FRANSHEL~~, an employee of BROTHMAN, during which conversation the name of HERSH RABINOWITZ, a former employee of BROTHMAN, was mentioned. (u)

On February 12, 1947, one Dr. ~~PALMA~~ (ph), Room 1819, 1440 Broadway, New York City, endeavored unsuccessfully to contact BROTHMAN. (u)

T-4 reported on the same date, that Mr. ~~PIELER~~, telephone number Evergreen 8-0036, endeavored to contact BROTHMAN. (u)

T-4 reported on March 25, 1947 that MIRIAM MOSKOWITZ contacted NEEDLEMAN at Amtorg during which she discussed the latest business ventures of the BROTHMAN firm. She stated that the LEVINE deal had fallen through but that the D.D.T. business in India is going along nicely. She also mentioned that Dr. ~~POM~~ (ph) had invited BROTHMAN to England during the month of April to "sign with them." She stated that Dr. POM had been in the United States during the past month at the Hotel Alden and is interested in the manufacture of plastics. (u)

T-4 reported on April 7, 1947 that BERNARD MISHKIN, an associate of BROTHMAN, went to London, England on April 7, 1947 by Pan American Airways, returning to New York on April 12, 1947. This source stated that MISHKIN had made the trip to see JACOB POMERANILAC in London concerning an agreement to manufacture plastics. (u)

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*See Serials #1*  
On March 28, 1947, a male individual who identified himself as ~~\*HANDSOME~~ contacted BROTHMAN advising that early the following week he was entertaining one HAROLD WINE (ph) at dinner and wanted BROTHMAN to meet WINE. He explained that WINE was the assistant to WENDELL ~~\*BERGE~~, the representative of the Department of Justice to the Atomic Energy Committee. (u)

On April 1 and April 2, 1947, a physical surveillance was maintained on BROTHMAN in an effort to identify "HANDSOME" with negative results. (u)

Again on April 10, 1947, T-4 reported that "HANDSOME" again contacted BROTHMAN stating that he would see BROTHMAN at his office at 5:15 P.M. However, T-4 later reported that this individual changed the appointment to 2:00 P.M. the following day. Again a physical surveillance was placed on BROTHMAN'S office in an effort to identify this individual with negative results. (u)

T-5 has reported that BROTHMAN continues to be in contact with Dr. MARIO L. OTTO ~~\*LENCHI~~, 183 Brown Street, Providence, Rhode Island. It was this same source that advised that BROTHMAN was in contact with B. ~~\*MCHLETT~~, 220 East 23rd Street. (u)

T-5 reported that on January 22, 1946 a contact was made by the "Music Room", 129 West 44th Street, which firm is known to be wanted by ERIC ~~\*BERNAY~~, a known close associate of ARTHUR ~~\*DIMS~~, Soviet agent. (u)

Confidential Informant T-6, of known reliability.

[REDACTED] (S) b1  
[REDACTED] b1  
Further information in this was made available by T-6 or any other source. (u)



ALLEGATIONS OF ELIZABETH T. BENTLEY AND SUBSEQUENT INTERVIEWS  
OF BROTHMAN AND HARRY GOLD

ELIZABETH T. ~~X~~BENTLEY has advised that in about May, 1940, she was introduced to BROTHMAN, whose photograph she identified, by JACOB ~~X~~GOLOS, known Soviet espionage agent, who told her that BROTHMAN would furnish her with certain blue prints. She stated that in the summer of 1940 until the fall of that year she met with BROTHMAN about ten times and obtained the blue prints from him. On some occasions, she stated that BROTHMAN gave the blue prints to GOLOS and all other times to her. She stated that she usually met BROTHMAN at Mosler Safe Company, 5th Avenue and 32nd Street, New York City, after which they would go to dinner and BROTHMAN would turn over the blue prints. On several occasions, copies of the blue prints were made by GOLOS and the originals returned to BROTHMAN. BENTLEY was not certain what the blue prints contained. In the fall of 1940, BENTLEY stated that GOLOS was disgusted with BROTHMAN and that he was turning BROTHMAN over to someone else. (u)

On May 29, 1947, ABRAHAM BROTHMAN was interviewed in his office, Room 1212, 2948 - 41st Avenue, Long Island City, New York. BROTHMAN was first questioned regarding his submitting information or furnishing blue prints to any individuals who might have connections with a foreign government. BROTHMAN stated that he had furnished blue prints to a number of individuals, and it was a common practice in the engineering field to submit blue prints to certain individuals who might possibly be in a position to obtain contracts for a firm. (u)

BROTHMAN was then specifically questioned as to whether or not he had been acquainted with an individual by the name of JACOB GOLOS. BROTHMAN stated that he could not recall this name, and a picture of GOLOS was exhibited to him. BROTHMAN denied knowing GOLOS at this time. Thereupon a picture of informant GREGORY was exhibited to BROTHMAN. BROTHMAN identified ~~X~~GREGORY as an individual whom he knew as ~~X~~HELEN." BROTHMAN was thereupon vigorously questioned as to his acquaintanceship with "HELEN." He then admitted that he did recognize the photograph of GOLOS but was unable to state the name of this individual. BROTHMAN then related the following concerning his knowledge of JACOB GOLOS and "HELEN:" (u)

According to BROTHMAN, sometime in 1938 or 1939 an individual came to him at his office at 114 East 32nd Street, at which time BROTHMAN was operating a firm under the name of the Republic Chemical Machinery Company, which company was associated with the Hendrick Manufacturing Company at Carbondale, Pennsylvania. This individual told BROTHMAN that he had con-

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tacts with the Russian Government and that he was in a position to get contracts from the Russian Government for BROTHMAN, if BROTHMAN would turn over to him blue prints of certain products BROTHMAN was working on at that time. BROTHMAN stated that the blue prints were his own property and they were for the most part blue prints of shafts, vats, and other equipment necessary in the operation of a plant manufacturing chemicals. (u)

According to BROTHMAN, GOLOS visited his office on several occasions and sometime following his original visit, he introduced him to an individual known only as "HELEN." BROTHMAN stated that he was under the impression that "HELEN" was secretary to GOLOS. GOLOS advised BROTHMAN that "HELEN" would in the future obtain the blue prints which he had been accustomed to turn over to GOLOS. (u)

"HELEN" visited BROTHMAN'S office over a dozen times during 1938-1939-1940 and sometime in 1940, "HELEN" stopped coming to his office and another individual named HARRY GOLD came to his office and said he represented GOLOS, the individual BROTHMAN had already identified as the man who made the original contact with him. GOLD visited BROTHMAN'S office on a number of occasions during 1940 and 1941. BROTHMAN stated that GOLD, at that time, was living in Philadelphia and used to make the trip to New York approximately every three weeks and obtain these blue prints from BROTHMAN. He said that to the best of his recollection the last time GOLD picked up the blue prints was late in 1941 or early in 1942. (u)

BROTHMAN was then questioned as to the whereabouts of HARRY GOLD, to which he replied that GOLD is presently employed by him as a chemist in his laboratory in Elmhurst, Long Island. BROTHMAN emphatically stated that GOLD was the last individual to pick up any blue prints or material which was to be furnished to GOLOS. He also stated that he did not know the present whereabouts of GOLOS and denied that he was ever contacted by any other individuals other than "HELEN" and GOLD as individuals who represented GOLOS. (u)

BROTHMAN was questioned as to the nature of the blue prints that he had turned over to GOLOS, at which time he displayed the blue prints, copies of which he still had in his offices, and an examination of the blue prints was made and it was determined that they were all concerned with blue prints of shafts, filters, vats and other machinery used in the manufacture of chemicals. BROTHMAN stated that some of the blue prints which he turned over to GOLOS and "HELEN" as well as to GOLD were returned to him, but others were retained by them. He emphatically denied that he had ever turned over any blue prints which were of a restricted or secret nature pertaining to the war effort of the United States or any plans which the United States might be concerned with at the time. (u)

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Relative to the Hendrick Manufacturing Company at Carbondale, Pennsylvania, BROTHMAN stated that he himself had founded the Republic Chemical Machinery Company which was set up as an engineering and designing company dealing solely with instruments and material to be used in the manufacture of chemicals. He stated that at the time he had formed the Republic Chemical Machinery Company, he was associated with the Hendrick Manufacturing Company and worked with that company until 1942. BROTHMAN added that all of the blue prints which had been turned over to the individuals mentioned hereinbefore were his own personal property belonging solely to the firm that he had founded. (u)

BROTHMAN was specifically questioned as to how he had become acquainted with JACOB GOLOS. He replied that possibly GOLOS knew of his firm through advertising in the various chemical magazines. He emphatically stated that this was the only possible way that GOLOS would get in touch with him and denied that anybody had ever sent GOLOS to him. BROTHMAN then stated that it was a common practice in the engineering field to turn over blue prints to various individuals in an effort to obtain contracts. He also stated that this was his sole purpose in turning over the blue prints to GOLOS; namely, that GOLOS had stated that he was in a position to obtain contracts from the Russian Government. (u)

BROTHMAN was questioned regarding his activities and contacts with the Russian Government. He stated that he had submitted various contracts to the Soviet Purchasing Commission and the Amtorg Trading Corporation but that he had never obtained a contract from either of these two agencies representing the Russian Government. He offered the information that he had recently obtained a contract from the Chinese Government and that he had obtained this contract by the same means that he had used in obtaining all of his contracts; namely, by submitting plans and blue prints to individuals representing the Chinese Government, and they had given him the contract for the development of a material which they hoped will eventually reduce the cost of manufacturing lucite. (u)

BROTHMAN was then specifically questioned as to whether or not he had ever been associated with the Communist Party or had attended any of the meetings or Communist affairs. BROTHMAN replied that he was a member of the Young Communist League during the time that he attended Columbia University; namely, in 1933. BROTHMAN stated that he did not attend any Communist Party meetings at the present time nor was he actively engaged in any Communist Party affairs. (u)



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BROTHERMAN was then questioned as to whether or not he had ever suspected that JACOB GOLOS was engaged in espionage activities. BROTHMAN replied that during the time that the Canadian espionage case broke in Canada in 1946 in reflection he became suspicious of GOLOS and thought possibly he was engaged in the type of activity that existed in Canada. (u)

BROTHERMAN offered the information that he was a member of the Political Action Committee and had attended meetings of that organization. (u)

Re: HARRY GOLD *from [unclear] on Harry Goldnitsky*

The following investigation concerning HARRY GOLD was conducted by Special Agents DONALD E. SHANNON and FRANCIS D. O'BRIEN on May 29, 1947: (u)

GOLD is the individual to whom ABRAHAM BROTHMAN turned over blue prints which he had in his possession, and GOLD also is the individual who obtained these blue prints at the express direction of JACOB GOLOS, now deceased but who was an agent of the Russian Government. (u)

GOLD was interviewed on May 29, 1947, in the A. Brothman Associates Laboratory, 8503 - 57th Avenue, Elmhurst, Long Island. GOLD stated that he was born December 12, 1910, in Switzerland and that he came to the United States in 1914 with his parents, SAM GOLD and CELIA GOLD, both of whom were born in Russia. GOLD stated that his parents came to the United States under the name of GOLODNITSKY but changed their names at the time they were naturalized. GOLD stated that he moved to Philadelphia after a short time and attended the public schools of Philadelphia, and in 1929 he was employed by the Pennsylvania Sugar Company in their laboratories. (u)

Subsequent to this time, GOLD attended night school at the Drexel Institute in Philadelphia, the University of Pennsylvania, and Columbia University, and he shortly thereafter obtained a leave of absence from the Pennsylvania Sugar Company in order to attend Xavier University at Cincinnati, Ohio, from which university he received a degree of Bachelor of Science Summa Cum Laude in 1940. GOLD gave his address in Philadelphia as 68-23 Kindred Street where his parents presently reside. GOLD stated that he was presently renting a room at Elmhurst, Long Island, and that he commutes to Philadelphia on week-ends. His address in Long Island was given as 4209 Hampton Street, Elmhurst. GOLD is residing with a family named PEREIRA at this address. (u)

In the course of the interview, HARRY GOLD advised that he had been employed off and on since 1929 with the Pennsylvania Sugar Company. During his employment with this company, he became friendly with an individual

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by the name of CARTER HOODLESS whose father was an official in the Pennsylvania Sugar Company. In October, 1940, GOLD advised, he attended a meeting of the American Chemical Society at the Franklin Institute in Philadelphia, Pennsylvania, together with CARTER HOODLESS. At the conclusion of the meeting, HOODLESS introduced him to an individual whom he recalled as JOHN GOLUSH or GOLISH (ph). A photograph of JACOB GOLOS was then exhibited to HARRY GOLD, and he identified this photograph as that of JOHN GOLUSH of GOLISH to whom he was introduced by CARTER HOODLESS in October, 1940. (u)

At the conclusion of this meeting at the American Chemical Society and after the introduction had taken place, HARRY GOLD advised that he and GOLOS went to a restaurant on Broad Street in Philadelphia. He was unable to recall specifically the name of the restaurant but thought that it might be LEW TENDLER'S RESTAURANT. They remained at the restaurant until 2:30 A.M. In the course of their conversation, GOLOS made the following proposition to HARRY GOLD. He advised him that he had some connections with some individuals in a foreign country, not naming the country, and that he had connections with an individual in New York City by the name of ABRAHAM BROTHMAN and BROTHMAN was turning over to him certain blue prints which had a connection in the chemical field. GOLOS told GOLD that he had to have a recognized chemist who would go to New York City, make contact with ABRAHAM BROTHMAN, obtain from him certain blue prints, and then evaluate these blue prints on a chemical basis. GOLD stated that no financial agreement was entered into but that there was an understanding that he would receive some reward for the work he was to perform. (u)

GOLD stated that about two weeks after this meeting, he telephoned ABRAHAM BROTHMAN in New York City and introduced himself to him over the telephone as a representative of JOHN GOLUSH or GOLISH and made an appointment to come to New York City to see BROTHMAN within a week or so. Within a week or two after this telephone call and sometime in November, 1940, HARRY GOLD made his first trip to New York City where he contacted ABRAHAM BROTHMAN. This meeting, according to GOLD, took place in the evening in a restaurant in the downtown section of New York City. GOLD was unable to recall the name of the restaurant. The two had dinner together and BROTHMAN turned over the blue prints to him. (u)

GOLD stated that for the next six months he made visits to New York City on the average of every three weeks. All of these trips were made in the evening as HARRY GOLD stated he had to attend to his job in the daytime. He also advised that he returned to Philadelphia on the same evening that he came to New York City and that on no occasion did he stay overnight in New York City during this six months' period. (u)

During this same period he received four or five phone calls from JOHN GOLUSH or GOLISH and in all of these telephone calls, GOLUSH would state that they would have to get together very shortly for a meeting, which meeting, according to GOLD, never took place. The last phone call from GOLUSH or GOLISH was made in May, 1941. No further word was heard from him, according to GOLD. (u)

GOLD stated that after his second or third trip to New York City and the phone calls from GOLUSH or GOLISH, he felt that there was nothing to the proposition and he became more or less disinterested in it. However, in the meantime, he and ABRAHAM BROTHMAN had become quite friendly and ABRAHAM BROTHMAN exhibited an interest in HARRY GOLD'S career as a chemist. In this regard, GOLD stated that BROTHMAN gave him several odd jobs to perform in his capacity as a chemist and that he paid him for this work. It was through this contact, according to HARRY GOLD, that he subsequently became employed by ABRAHAM BROTHMAN in February 1946. GOLD stated that ever since 1941, ABRAHAM BROTHMAN had been interested in having him come with his organization on a full-time basis, but it was not until February 1946 that he could see his way clear to accept such employment. (u)

HARRY GOLD was questioned very closely as to any financial arrangements that had been entered into between GOLUSH or GOLISH and him. He stated that he did not receive one cent from him and that he had only seen GOLUSH on the one occasion in October 1940. He was then asked who paid his fare for these trips he made every three weeks for a six months' period from Philadelphia to New York and return. He stated that he himself stood the expenses for the first two trips and that after he became friendly with ABRAHAM BROTHMAN, BROTHMAN would give him a \$5.00 bill to sustain the expenses of his trips to New York and return. (u)

The following is a description of HARRY GOLD as obtained from observation and interview:

Name:	<u>HARRY GOLD</u>
Age:	36
Born:	December 12, 1910, Switzerland
Residence:	68-23 Kindred Street, Philadelphia, Pennsylvania
Height:	5' 6"
Weight:	180 pounds
Eyes:	Hazel
Hair:	Brown, wavy
Build:	Short and fat
Characteristics:	Round, full face, prominent protrusion of eyes. (u)

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ADDITIONAL CONTACTS OF SUBJECT

In the course of the physical surveillance on BROTHMAN from November 28 to December 28, 1945, the following owners of automobiles were observed in the vicinity of BROTHMAN'S laboratory.

NAT ~~X~~GOLDBLUM,  
783 Troy Avenue,  
Brooklyn, New York

PERCY H ~~X~~ESTRIDGE,  
114-27 134th Street,  
South Ozone Park, Long Island.

GEORGE ~~X~~ERICKSON,  
31-31 93rd Street,  
Jackson Heights, Long Island.

RALPH ~~X~~HARABES,  
3307 37th Avenue,  
Long Island City. (u)

Also an automobile belonging to CHARLES ~~X~~MANGULE, 167 Circle, Little Ferry, New Jersey, was observed near BROTHMAN'S business premises. (u)

On February 27, 1950, ARTHUR R ~~X~~WEBER, former business associate of BROTHMAN, was interviewed by the New York Office in an effort to obtain the identities of additional contacts of BROTHMAN at the time he was able to furnish the names of BERNARD OSGOOD ~~X~~KROOPMAN, Columbia University, professor, and PERCY NADEL. (u)

Later on March 3, 1950, WEBER furnished the following additional contacts of BROTHMAN: (u)

SERGE ~~X~~JARVIS - See p 27

WEBER described him as a New York City attorney who was representing a group of persons in 1942 or 1943 who were interested in buying a brewery in New Jersey with a view towards using the premises to manufacture Lactic Acid. JARVIS, an acquaintance of BROTHMAN, contacted BROTHMAN and WEBER and requested them to organize the brewery. They recommended against the use of the premises. (u)

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LEO MITTLEMAN

WEBER stated that BROTHMAN contracted MITTLEMAN for legal advise on a engineering contract which never materialized. (u)

ALEX BRAND

WEBER stated that BRAND is another New York attorney who was retained by BROTHMAN in 1943 to handle a contract regarding work with the Bridgeport Brass Company. (u)

ARTHUR MARKMAN (ph)

MARKMAN was an old friend of BROTHMAN and the BROTHMAN family and WEBER first met him while working with BROTHMAN at the Hondrick Manufacturing Company in 1941. He stated that MARKMAN was an officer in a bank located in the vicinity of 14th Street in Manhattan and that BROTHMAN'S wife had apparently worked as a secretary for MARKMAN. (u)

FRANK KEPPLER (ph)

Arthur P. WEBER stated he first met this person in late 1943 when he came to visit BROTHMAN at Chemurgy Design Corporation. KEPPLER was a personal friend of BROTHMAN and apparently there was no business connections between them although WEBER believes he was in a similar business to that of BROTHMAN. (u)

At a subsequent interview, WEBER identified a picture of HARRY GOLD as the individual known to him as FRANK KEPPLER. (u)

JACK MILLS

WEBER stated that MILLS was another acquaintance of BROTHMAN'S and was a junior executive with the Bridgeport Brass Company. WEBER stated that contact was made with MILLS in an effort to get a contract for consulting and design work with the Bridgeport Brass Company. It is possible that MILLS is identical with JACK MILLER mentioned as an acquaintance of BROTHMAN by T-2 and T-4. (u)

C. M. RASH

He stated that RASH is a former comptroller of Goldman-Sachs. RASH contacted BROTHMAN and WEBER on several occasions, at which time he was acting as an agent for buyers and sellers of chemical plants. As of August, 1949, RASH was associated with the American Weighing Corporation.

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SHINDLER

WEBER stated that this individual use to visit BROTHMAN at the Chemurgy Design Corporation and that he operated a small paint factory in Brooklyn. (u)

*Arthur P.*  
In the interview with WEBER, WEBER stated that he did not get along with BROTHMAN due to business difficulties and BROTHMAN'S Left Wing tendencies. He stated that OSCAR VAGO, EMIL BARISH, JUL'S KORCHEIN, business associates of BROTHMAN, were also Leftists in their thinking to which WEBER also objected. (u)

With respect to the contract which BROTHMAN obtained to construct aerosol Bombs, WEBER advised that BROTHMAN got this contract in about August 1943 and that the Bridgeport Brass Company was the prime contractor and the Regal Chemical Company a subcontractor. He believed that the contract was completed in the late summer or early fall of 1944, therefore, it would appear at the time [redacted] was reporting on BROTHMAN'S affairs, the aerosol contract was either completed or nearly completed. [redacted] (u) b1

WEBER stated that he had made several business trips to Chicago, Wilmington, Delaware and Lancaster, Pennsylvania and other places but recalls only business contracts having been made by BROTHMAN. (u)

WEBER described BROTHMAN as a conceited, domineering individual who is a good chemical engineer but tries to give the impression that he is much better. He stated that it was customary for BROTHMAN to have luncheon with several of the individuals employed at Chemurgy each day and spend most of the lunch hour bragging about his accomplishments. (u)

IDENTIFICATION OF BROTHMAN'S CONTACTS

BERNARD OSGOOD KOOPMAN.

Confidential Informant T-19, of unknown reliability, advised that KOOPMAN was born in Paris, France in 1900 of American parents. He graduated from Harvard University in 1924 obtaining a P.H.D. in 1926. He has been at Columbia University as a faculty member since 1928. He was Assistant Professor of Mathematics until March, 1944 when he obtained a leave of absence to do work for the government at Harvard University. KOOPMAN returned to Columbia University in December, 1945 where he is now full professor and lives at 430 West 118th Street, New York City. Confidential Informant T-20, of unknown reliability, advised that KOOPMAN registered as a Socialist in 1935. He married for the second time in about 1938. (u)



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PERCY NADEL

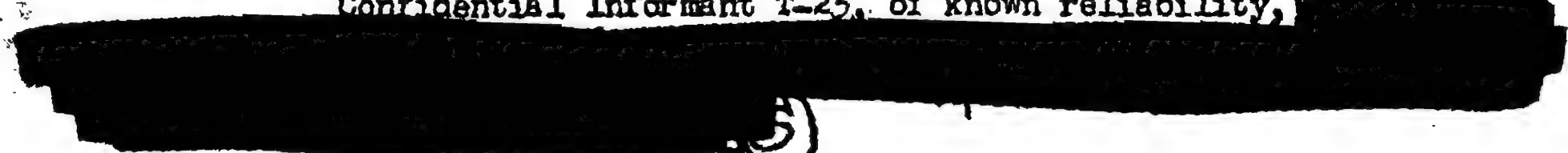
*adele Nadel*  
Confidential Informant T-21, of unknown reliability, advised that in 1944 and 1945, NADEL operated the Delton Products Corporation, 485 Fifth Avenue, New York City with himself as President and his wife as Vice-President and Captain JOSEPH SUTTON as Secretary-Treasurer. NADEL'S office is now located at 154 Nassau Street and he lives at 79 Schenck Avenue, Brooklyn. Confidential Informant T-22, of known reliability, advised that NADEL was born in 1896. His wife's name is ADELE. NADEL and his wife were members of the IWO, Lodge 600 in New York City in 1948 and 1949. (u)

VLADIMIR A. TVERIANOVICH

Confidential Informant T-23, of known reliability, *State*  
 (u)

DR. ERNST BERGMAN

*Visa*  
Inquiry at the Hotel Salisbury, 123 West 57th Street, New York revealed that one DR. ERNST BERGMAN had occupied a suite belonging to CHIAN WEIZMANN in December, 1946. Confidential Informant T-24, of known reliability,  
 (u)

Confidential Informant T-25, of known reliability, *61*  
 (u)

Investigation by the Philadelphia Office reflects that BERGMAN performed work in the laboratories of the Publicker Industries, Philadelphia, Pennsylvania as a result of an agreement by the Weizmann Institute of Palestine and the Publicker Industries. These two organizations had made

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an agreement whereby Publicker Industries would handle all patent arrangements for the Weizmann Institute in the United States. In addition, the Weizmann Institute furnished the consultant services of persons like BERGMAN. (u)

POWELL

T-2 reported that BROTHMAN was in contact with an individual named POWELL, Room 405, Park Square Building, Boston, Massachusetts. Boston Office ascertained that Room 405 in that building is occupied by the firm Flagg, Brackett, Durgin, manufacturers' agents. The company employs nine people in Boston and has a sales office at 250 West 59th Street, New York City. The firm is a partnership formed on January 1, 1944 to act as sales engineers for manufacturers' agents in New England. It is engaged principally in selling to construction companies which are engaged in light manufacturing and specializing in power plant and oil refinery equipment. POWELL has not been identified further. (u)

LUDWIG ROSENSTEIN

T-2 has reported that BROTHMAN was in contact with a Dr. ROSENSTEIN in 1945, telephone number MU 5-2466. The 1945 Manhattan telephone directory lists LUDWIG ROSENSTEIN, Consultant, 405 Lexington Avenue. He also maintains a laboratory at 114 East 32nd Street and residence at 125 East 72nd Street, New York City. New York indices are negative on ROSENSTEIN. (u)

SERGE JARVIS

Confidential Informant T-13, of known reliability, advised that in about 1945, JARVIS was residing at 17 West 67th Street, New York City. He was born in 1905 and has been engaged in the practice of law in New York City since 1936. He is a graduate of New Jersey Law School and received his early education abroad. Confidential Informant T-14, of known reliability, reflects that JARVIS was born under the name SAUL ~~WITZ~~ on May 22, 1905 in Russia and was naturalized in the Bronx County, New York on January 23, 1928. He indicated that he had attended Central High School, Newark, New Jersey 1923-1924, New Jersey Law School 1924-1927 and City College of New York, 1929. He served his clerkship with CHARLES ~~RECHT~~, attorney for the Russian Government, 10 East 40th Street, New York City. T-14 also advised that JARVIS worked under JOSEPH ~~MICHAEL~~ in the Law Department of Amtorg Trading Corporation when that firm was located at 261 Fifth Avenue, New York City (u)

Confidential Informant T-15, of known reliability, reflected that JARVIS, in October, 1942, was employed as General Counsel for the Canadian Radium and Uranium Corporation, 630 Fifth Avenue, New York and handled legal matters for BORIS ~~PREGEL~~, President of the Radium and Uranium Corporation. As of 1945, JARVIS was sharing office space with CHARLES ~~RECHT~~. (u)

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On July 3, 1946, JARVIS was issued a passport to visit England, France and Czechoslovakia in connection with the import and export business of clients. He left the United States on July 9, 1946 and returned on August 7, 1946. As of July, 1947, JARVIS and his wife were residing at 11 69th Street, New York City. (U)

DR. JOSEPH BLUMENFELD

According to information received from Confidential Informant T-16, of unknown reliability, [REDACTED] 67D

[REDACTED] (U)

Confidential Informant T-17, of known reliability, advised that BLUMENFELD was born on September 2, 1886 at Kichenev, Russia. In 1942, he lived at 322 West 72nd Street and arrived in the United States on June 30, 1942, at which time he was destined to the residence of CHAIM WEIZMANN, his brother-in-law, then living at the Hotel St. Regis, New York City. His wife, [REDACTED] BLUMENFELD, was born in Rostov, Russia in 1886 and entered the United States on the same date as her husband. BLUMENFELD listed his employment as a [REDACTED] engineer. (U)

The Protective Metals Process Corporation, 51 East 42nd Street, New York City was organized by BLUMENFELD in June, 1943 with BLUMENFELD as Director and Vice-President. This enterprise was set up to conduct research to develop protective coatings for metals. The corporation discontinued activity about July, 1944 due to the failure to develop the desired process. In 1946, BLUMENFELD became active in the Weber Metals Corporation, Bronx, New York, manufacturers of cigar lighters. (U)

Confidential Informant T-18, of unknown reliability, has stated that he has never known BLUMENFELD to express political sentiments and is convinced of BLUMENFELD'S loyalty. (U)

CURRENT ACTIVITIES OF BROTHMAN

BROTHMAN lives in Apartment 6F at 4108 42nd Street, Sunnyside, Long Island. He is the owner of a 1949 maroon, two door Oldsmobile Sedan bearing white wall tires and 1950 tag RC-2051. (U)

A current surveillance picture of BROTHMAN was obtained on February 2, 1950. BROTHMAN still operates the A. Brothman and Associates at Room 1215, 2928 41st Avenue, Long Island City. (U)



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Confidential Informant T-7, of unknown reliability, has advised that BROTHMAN employs a clerk, a secretary, and a male assistant, believed by T-7 to be of Hindu extraction. T-7 states that BROTHMAN maintains irregular hours and at times is known to come into the building at 2:00 or 3:00 A.M. and work for the rest of the night. In addition, T-7 knows that BROTHMAN makes periodic trips to Philadelphia for two or three days at a time during which there is no activity in his office. (U)

Apparently BROTHMAN still uses the premises at 8503 57th Avenue, Elmhurst, Long Island which is owned and operated by the Peacock Roll Leaf Mill. The current Queens telephone directory lists BROTHMAN'S office at 2928 41st Avenue, Long Island City and his laboratories at 8503 57th Avenue Elmhurst, Long Island. The physical surveillance on BROTHMAN on the evening of January 22, 1950 revealed that he visited 8503 57th Avenue after leaving his Long Island City office. (U)

Confidential Informant T-8, of known reliability, advised on March 28, 1949 that BROTHMAN operates A. Brothman and Associates at 2928 21st Street, New York City. His partner in this business venture is MIRIAM MOSKOWITZ. T-8 stated that the business was established in October, 1946 and its net worth in March, 1949 was in excess of \$15,000. On October 11, 1946, the firm was registered by BROTHMAN, MOSKOWITZ and OSCAR J. VILGO. On June 2, 1948, VILGO sold his interest to his partner. MIRIAM MOSKOWITZ is 32, single and a graduate of City College of New York in 1942. From the spring of 1942 to August, 1944, she was employed as a secretary in the War Manpower Commission, New York City. As of March 1949, the firm was engaged in developing work for firms in the United States and foreign countries, including the Chinese Government. The firm is described as experienced chemical engineers which employs laboratory assistances when needed. T-8 also stated that BROTHMAN maintains a laboratory at 8503 57th Avenue, Elmhurst, Long Island. T-8 was unable to furnish any information on the Phenix Service Bureau which name is listed on the building and on BROTHMAN'S door. (U)

Confidential Informant T-9, of known reliability, advised that A. Brothman and Associates maintains a bank account at the National City Bank, Queens Plaza Branch and has an average balance of about \$200.00. The balance as of February 23, 1950 was \$408.40. The highest balance during the month of February, 1950 was \$504.17. The total deposits in the month of February amounted to about \$1,200. BROTHMAN also maintains a personal account jointly with his wife, NAOMI, the balance of which was \$76.48 as of February 23, 1950. (U)

Confidential Informant T-10, of known reliability, advised that BROTHMAN, during the months of February and March, 1950, has been in contact with the following firms and individuals: (U)

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The Bristol Company,  
Post Office Box 1790,  
Waterbury, Connecticut

N. Y. City Business,  
Classified Directory,  
303 Washington Street,  
Brooklyn, New York

Kymmene, Aktie Bolag,  
Kuusankoski,  
Finland.

S. S. ~~W~~asan,  
University of Utah,  
Men's Dormitory,  
Building 459,  
Salt Lake City, Utah.

Finn and Company,  
2850 8th Avenue,  
New York 30, New York

Automatic Switch Company,  
391 Lakeside Avenue,  
Orange, New Jersey.

The Royal Tyne Works  
2 Kamps Town,  
Tiruchirappalli,  
S. India.

Mallinckrodt Chemical Works,  
72 Gold Street,  
New York 8, New York

New York Public Library  
Photographic Service,  
5th Avenue and 42nd Street,  
New York 18, New York

R. C. A. Inc.,  
66 Broad Street,  
New York 4, New York

Mactell Service Company,  
489 Fifth Avenue,  
New York 17, New York

Photoswitch, Inc.  
77 Broadway,  
Cambridge 42, Massachusetts

Rohm & Hass Company,  
Washington Square,  
Philadelphia 5, Pennsylvania.

Mesun Engineering Company, Ltd.  
5-7, Second Line Beach,  
Madras-1,  
India.

Kymin Osakeyhtes  
Kuusankoski,  
Suomi, Finland

Sri: R. V. ~~R~~amani  
Care A. Brothman & Associates,  
2928-41 Avenue,  
Long Island City 1, New York.

~~L~~onza,  
Basel, Helvetia.

Sri. R. V. Ramani,  
India

Eimer and Amend  
Greenwich and Morton Streets,  
New York 14, New York.

American Labor Party,  
43-42 48th Street,  
Long Island City 4, New York (u)

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The Dictaphone Corporation,  
375 Howard Avenue,  
Bridgeport, Connecticut

U.S. Department of Commerce  
Bureau of Foreign &  
Domestic Commerce,  
Field Service,  
42 Broadway,  
New York, New York.

DeWitt Clinton Alumni Assoc.  
Mosholu Pkway & Paul Avenue,  
New York 63, New York.

Department of Justice,  
Immigration Service,  
New York 25, New York.

Industrial Process Engineers,  
8 Lister Avenue,  
Newark, New Jersey.

Suite 1501,  
192 Lexington Avenue,  
New York 16, New York.

N. Y. Telephone Company,  
Post Office Box 11,  
Jackson Heights, New York.

Automatic Switch Company,  
391 Lakeside Avenue,  
Orange, New Jersey.

Industrial Process Engineers,  
8 Lister Avenue,  
Newark, New Jersey.

Associated Aviation,  
90 John Street,  
New York, New York.

C. H. Kibble Company,  
41 Park Row,  
New York, New York.

D. Lichtman,  
Martin D. Gettry,  
276 Fifth Avenue,  
New York, New York.

The Ferisciner of Chem. and  
Travanlore, Lt.,  
Trichinopoly,  
S. India.

Inland Steel Company,  
Chicago 3,  
Illinois.

Eimer & Amend,  
Greenwich & Morton Streets,  
New York 14, New York.

Chicago Stainless Equipment Corporation  
5001 Elston Avenue,  
Chicago, Illinois.

D. Pizer,  
% Commercial Plastics, Ltd.,  
Raunlliers Building,  
Hills Place,  
London, N. I.

Eitel-McCullough, Inc.  
San Bruno, California.

University of Minnesota,  
Institute of Technology,  
Minneapolis 14, Minnesota.

The Matheson Company, Inc.  
East Rutherford,  
New Jersey.

(u)



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Keuffel & Esser Company,  
Post Office Box 278,  
Church Street,  
New York, New York

Keuffel & Esser Company,  
Adams & Third Street,  
Hoboken, New Jersey.

Republic of India,  
The Fertilisers & Chemicals  
Travancore Ltd.,  
Odyasamanda, India.

Chemical Engineering Catalog,  
Reinhold Publishing Corp.,  
330 West 42nd Street,  
New York 18, New York

Photoswitch, Inc.  
77 Broadway,  
Cambridge 42, Massachusetts

McGraw-Hill Publishing  
Company, Inc.,  
McGraw-Hill Building,  
530 West 42nd Street,  
New York 18, New York

Eimer and Amend  
Laboratory Apparatus-  
Chemicals-Drugs,  
Greenwich & Morton Streets,  
New York 14, New York.

A. Barnett Green,  
Hotel Breslin,  
Broadway & 29th Street,  
New York, New York

U.S. Government Printing Office,  
Division of Public Documents,  
Washington, D. C.

Fisher Scientific Company,  
717 Forbes Street,  
Pittsburgh, Pennsylvania.

Hosinger & Bode Inc.,  
Chatham Phenix Building,  
Long Island City 1, New York.

New York Telephone Company,  
Post Office Box 12,  
Long Island City 1, New York.

Consolidated Edison Company of  
New York, Inc.  
Post Office Box 131,  
General Post Office,  
Brooklyn, New York.

Consulate General of Switzerland,  
444 Madison Avenue,  
New York 22, New York.

Crystal Spring Water Company,  
132nd Street and Brook Avenue,  
New York 54, New York.

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It would appear from the information furnished by T-10 that the assistant now employed by BROTHMAN is ~~RAMINI~~. (u)

Confidential Informant T-11, of known reliability, advised that ~~BROTHMAN~~ has been in contact with the following individuals and firms:

NEVINS CHURCH PRESS,  
92 Midland Avenue,  
Glen Ridge, New Jersey.

Ulster Chemicals, Inc.,  
Cliffwood, New Jersey.

Miss G. ~~SWARTZMAN~~,  
86 West 56th Street,  
Bayonne, New Jersey

ARMAND G. ~~LOEB~~,  
H. Loeb and Sons,  
4642 Lancaster Avenue,  
Philadelphia, Pennsylvania.

Charles Lennig and Company, Inc.

Resinous Products and Chemical Company,  
Philadelphia, Pennsylvania.

PAUL ~~BERG~~,  
Hatboro, Pennsylvania

~~ROHM and Haas and Company,~~  
~~222 West Washington Square,~~  
~~Philadelphia.~~ (u)

Confidential Informant T-12, of known reliability, who was aware of BROTHMAN'S activities between February 16 and February 24, 1950, has advised that he made no significant contact during that period. T-12 advised that BROTHMAN usually works each evening after which he drives his secretary, MIRIAM MOSKOWITZ, to her home at 154 8th Avenue, New York, and returns to his apartment apparently with RAMINI, who is apparently living with BROTHMAN. (u)

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LEADS

Will expedite the coverage of all leads since the Bureau has indicated an interview with BROTHMAN may be authorized following the viewing of OSCAR J. VAGO in New York by ROBERT HEINEMAN on April 12, 1950. (u)

CHICAGO

At Chicago, Illinois P-5

Will identify EMANUEL GREEN, 7853 Essex Street, Chicago, Illinois. (u)

NEWARK

Will identify the following contacts of BROTHMAN:

At Garwood, New Jersey

ROBERT TUCKER, Garwood, New Jersey. P 9

At Hoboken, New Jersey

Mr. BOWEN, Bowen Engineering Company.

At Paterson, New Jersey

SILON H. STRICKLER, telephone number Sherwood 2-9778,  
Strickler and Company, 45 Church Street, Paterson, New Jersey.

At Little Ferry, New Jersey

CHARLES MANGULE, 167 Circle, Little Ferry, New Jersey.

At Bayonne, New Jersey.

Miss G. SWARTZMAN, 86 West 56th Street, Bayonne, New Jersey. (u)

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LEADS (CON'T)

BOSTON

At Cambridge, Massachusetts

Will identify a Mr. EARL, an engineer in Cambridge, Massachusetts.

At Boston, Massachusetts

Will endeavor to identify Mr. POWELL, Room 405 Park Square Building, Boston, Massachusetts.

At Leominster, Massachusetts

Will endeavor to identify HARRY LEVINE, Leominster, Massachusetts.  
(Commonwealth Plastics)

At Providence, Rhode Island

Will endeavor to identify DR. RUANI and DR. MARIO L. OTTO LENCHI, both of 183 Brown Street, Providence, Massachusetts.

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NEW YORK

At New York, New York

Will identify the following contacts of BROTHMAN by means of indices check and contact with Confidential Informants T-8 and T-13:

"Mr. SHURA", (possibly identical with SHURA SWAN).

EDWARD JACOBS - telephone number MU-2-6803.

LOU BERNE (ph).

Mr. FRISCHER

CY SILVERSTEIN

C. S. WAN

SEYMOUR (CY) MANDELKORN (ph) 67 Jane Street.

*Credit Bureau*  
*(Employee as of 12/45) P3*  
*(Employee as of 12/45) P1*  
*(21)*

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BERNIE PIDTO

Lieutenant OAS (ph) - Army Base

EMANUEL GREEN - *PS*

Mr. STEIGLE (ph) - American Russian Institute.

ALEX WEBER - telephone number BA 7-6348.

JACK MILLER

LEO MITTLEMAN, Attorney, - telephone number WO-2-3100.

Mr. HILL, Room 310, 610 Fifth Avenue, New York City.

FRED BRIEHL, Walkill, New York.

GERARD PIEL, Room 310, 620 Fifth Avenue, telephones CI 6-4725, CI 6-5343.

M. SPRINGER - telephone number EL 5-1123.

HARRY SLAVIN, 510 West 172nd Street, New York City.

Mr. KAHN, Consolidated Products Company,

LUDWIG MUSET (ph)

Mr. DEUTSCH - an engineer

HALPERN - an employee of BROTHMAN. *as of 12/45 - P4*

GONZALES

JACKSON

Mr. LECATUR (ph) (possibly connected with Flagg, Brackett & Durgin, Boston, Massachusetts.

Mr. POWELL, 250 West 59th Street, (Flagg, Brackett & Durgin, Manufacturers' agents.)

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~~TOP SECRET~~

MATTHEW ZARRED, 48th Street, Sunnyside, Long Island

THEORA SWAN

BILL RAHALL, Aqueduct Avenue, Bronx, New York - *Employee as of 5/16-71*

SOL FANSHEL, *employee? - P11*

JULIUS BRODY - PL 3-9533 or PL 3-9535

ALBERT OSBORNE

BEN SILVERMAN

LEO GOTTLIEB, - HA 2-8989 or Lambert 3-5833

HERSH RABINOWITZ *(former employee as of 1/47 - P15)*

DR. PALMA, (ph), Room 1819, 1440 Broadway, New York City

Mr. FIELER, - EV 8-0036.

E. MACHLETT, 220 East 23rd Street, New York City.

ERIC BERNAY

NAT GOLDBLUM 783 Troy Avenue, Brooklyn, New York.

PERCY H. ESTRIDGE, 114-27 134th Street, South Ozone Park, Long Island.

GEORGE ERICKSON, 31-31 93rd Street, Jackson Heights, Long Island.

RALPH HARABES, 3307 37th Avenue, Long Island City.

ALEX BRAND

ARTHUR MARKMAN (ph)

JACK MILLS

C. L. RASH

SHINDLER, operator of paint factory, Brooklyn, New York. *[u]*

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A. BARNETT GREEN, Breslin Hotel, New York.

JAMES KUNEN, 40 West 40th Street, New York City.

BERNARD MISHKIN, *associate of Nathan* *as of 4/47-P.*

Will contact American Airlines regarding BROTHMAN in an effort to determine the extent he has travelled on business or pleasure, it being noted he had an American Airlines Credit Card in May, 1946. (u)

Will determine from Immigration and Naturalization Service, 70 Columbus Avenue, New York, the nature of BROTHMAN'S business with Immigration and Naturalization Service as reported by T-10. (u)

Will interview BROTHMAN when authorized by the Bureau. (u)

Will question BROTHMAN in detail regarding his activities subsequent to the time that he was being contacted by HARRY GOLD, with particular emphasis on all his known dealings with the Russian Government. (u)

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CONFIDENTIAL INFORMANTS

The Confidential Informants mentioned in the report of SA JOHN R. MURPHY, JR. dated , April 5, 1950, at New York are as follows:

T-1

[REDACTED] (S) b1

T-2

Former Confidential Informant [REDACTED]

T-3

Anonymous

b2 b7D

T-4

Former Confidential Informant [REDACTED]

T-5

Mail cover maintained on the offices of ABRAHAM BROTHMAN in 1947.

T-6

[REDACTED] (c) b1

T-7

GEORGE HIRD, Building Superintendent at 2928 41st Avenue, Long Island City.

T-8

[REDACTED] b2 b7D

T-9

Records of the National City Bank, Bridge Plaza Branch, Long Island City.

T-10

Current mail cover on ABRAHAM BROTHMAN.

T-11

[REDACTED] b2 b7D

T-12

Physical surveillance on BROTHMAN from February 16 to February 24, 1950.

T-13

Records of the Credit Bureau of Great New York.

T-14

Records of the New York Bar Association which were check in connection with the investigation of SERGE JARVIS.

T-15

Records of Selective Service Board, Number 30, New York.

~~TOP SECRET~~

NY 100-95068

~~TOP SECRET~~

CONFIDENTIAL INFORMANTS (CON'T)

T-16	Confidential Informant [REDACTED] 62-67D
T-17	Records of the Immigration and Naturalization Service, 70 Columbus Avenue, New York City.
T-18	GEORGE DORIOT.
T-19	VERA SOUTHLAND, Secretary's Office, Columbia University.
T-20	Board of Election Records, New York City.
T-21	FRANK FARLEY, Donohue Rental Company, 489 Fifth Avenue, New York.
T-22	[REDACTED] 62-67D
T-23	PR-1 File, State Department (See letter of Washington Field Office, December 12, 1944).
T-24	BERGMAN'S visa application contained in Bureau files and set out in Bureau letter, March 8, 1950 in "FOOCASE, Espionage - R."
T-25	[REDACTED] (c) 61

REFERENCE: Report of SA FRANCIS J. GALLANT dated 9/19/49, New York.  
Bureau letter dated 2/16/50.

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SAC, Baltimore

~~TOP SECRET~~

April 23, 1950

Director, FBI

ABRAHAM BROTHMAN, wa.

ESPIONAGE - R

Bureau File No. 100-365040

Investigation is presently being conducted of Abraham Brothman with a view toward identifying the Soviet contact of Paul Julius Davis, known subject.

In August, 1944, Brothman organized his consulting engineers firm, Abraham Brothman and Associates, 114 East 32nd Street, New York City, which later moved to 29-28 41st Avenue, Long Island City. It appears that at the same time or shortly thereafter Brothman also organized the Abraham Brothman and Associates Laboratory, 8503 57th Avenue, Elmhurst, Long Island. (u)

It is requested that the Baltimore Office contact its informant to determine all available information concerning the employees of Brothman at the above-mentioned concerns. (u)

The Albany Office is requested to obtain all available information concerning the Brothman employees from the New York State Department of Labor, Division of Unemployment and Placement Insurance, and the New York State Tax Commission. (u)

This investigation should be conducted at the earliest possible moment and the results promptly be furnished to the Bureau and the New York Office, which is the office of origin. (u)

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cc - Albany  
New York City

EX-125

Classified by 319/87  
Declassify on: OADR

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Classified by 2835 LAG/oon  
Exempt from GDS, Category 2-3  
Date of Declassification Indefinite

APPROPRIATE AGENCIES  
AND FIELD OFFICES  
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DATE 6/1/78

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## Office Memorandum • UNITED STATES GOVERNMENT

TO : Director, FBI

DATE: May 3, 1950

FROM : SAC, New York

SUBJECT: ABRAHAM BROTHMAN, wa.  
ESPIONAGE - R

33832

Rebulet to Baltimore 4/28/50 in the above captioned case.

On May 2, 1950 WALTER BODE of the firm of Hosinger and Bode, Realtors, in the office building where BROTHMAN has space, advised as follows:

MIRIAM MOSKOWITZ, BROTHMAN'S secretary, recently discussed with him the possibility of obtaining additional space in the building for BROTHMAN. She stated that they needed more space in order to conduct chemical experiments, and also BROTHMAN is interested in obtaining left space for storage purposes. In this connection she stated that BROTHMAN now has space in an Elmhurst establishment which is used for conducting small chemical experiments, but that the lessor (probably the Peacock Roll Leaf Mill) is anxious to regain this space. She also mentioned that BROTHMAN has storage space in an unspecified New Jersey location.

BODE also indicated that as far as he knows BROTHMAN employs only MOSKOWITZ and a hindu with whom BROTHMAN works very closely at all times in the office presumably conducting chemical experiments. It is further believed from what was said by MOSKOWITZ, that BROTHMAN does not employ anyone at the Elmhurst address, which is undoubtedly 8503 57th Avenue.

The above is for the information of the Bureau and auxiliary offices.

cc: Albany  
Baltimore  
NY 65-15136  
NY 65-15185

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SERVICE UNIT  
SEARCH SLIP

F-19a

Supervisor \_\_\_\_\_ Room \_\_\_\_\_

Subj: OSCAR Vago

☒ Exact Spelling

☒ All References

☒ Subversive Ref.

☒ Main File

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~~100-3-4-6247 p. 15,~~ ✓

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~~65-56402-206 p. 9, 10,~~ ✓

~~161-2352-2,~~ ✓

~~100-3-4-6723 p. 19,~~ ✓

~~61-7231-132, 254 p. 56~~ ✓

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~~2222-2,~~ ✓

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~~33,~~ ✓

~~65-56402-2355 p. 4~~ ✓

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F-19a

SERVICE UNIT  
SEARCH SLIP

Supervisor \_\_\_\_\_

Room \_\_\_\_\_

Subj: Oscar Vago

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	1660 X P. 8	✓
	2606 P. 4	✓
100-360200		✓
100-365040		✓
121-7390		✓
65-56402	236 P. 64	✓

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Subj: Oscar J. Vago

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121-7390-20  
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100-10589-22, Repeat  
61-2231-289, p. 56, Repeat

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100-360260-1, Repeat  
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100-24699-3  
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Supervisor Anderson Room 4708

Subj: Miriam Marcowitz

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65-43302-5080p49

65-56402-4300p18

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4981p6,7

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100-24621-49p106

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SERVICE UNIT

4-22a

SEARCH SLIP

Supervisor Landson Room 9708

Subj: Miriam Mascanity

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DATE 3-11-87 BY 3092 PWT/cha

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FEDERAL BUREAU OF INVESTIGATION

This Case Originated At: NEW YORK

File No. 100-21623

Report Made At: CHICAGO, ILLINOIS ; Date Made: 5/4/50 ; Period: 4/17, 20, 21, 24, 27, 28, 5/1/50 ; Report Made By: W. RULON FAXMAN WRP-JCS

Title: ABRAHAM BROTHMAN, with alias: Abe Brothman ; Character of Case: SECURITY MATTER - C

SYNOPSIS OF FACTS:

WAB/Don 10-1-75  
CONFIDENTIAL AND ADMINISTRATIVE

EMANUEL GREEN, aka Manuel, Manny, resided at 7853 S. Essex Avenue, Chicago, subsequent to his discharge from U.S. Army on 12/12/45, but his present whereabouts is not known. GREEN was born in Chicago, Illinois. He is a Chemical Engineer by training. He has a brother LOUIS GREEN and a sister PEARL GREEN, who currently reside at the Essex Avenue address. Chicago credit agency and Chicago Police Department have no record pertaining to GREEN. Description set out. (u)

- RUC -

DETAILS:

AT CHICAGO, ILLINOIS:

Confidential Informant advised that in December 1945, he employed a young fellow by the name of GREEN, recently discharged from the Army, who was working in this position. BROTHMAN said that GREEN was a position in the plant. The informant was also advised that BROTHMAN was at the Chicago address 7853 Essex Avenue, Chicago, Illinois. (u)

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Approved & Forwarded: SAC Do Not Write In These Spaces

Copies  
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3 - New York (100-95068)  
3 - Chicago

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INDEXED - 20

EX-20

Chicago File 100-21623

EMANUEL GREEN, also known as  
Manual Green, Manny Green

RESIDENCE:

Mr. CARL R. STURMER, janitor, 7853 S. Essex Avenue, Chicago, Illinois, advises that about 1943 PEARL GREEN rented Apartment 308 at 7853 S. Essex Avenue, Chicago. Sometime in the latter part of 1945 or early 1946 her two brothers, EMANUEL and LOUIS GREEN, were discharged from the Armed Services and came to reside with their sister. LOUIS continues to reside at this address but EMANUEL got married about a year or a year and a half ago and moved elsewhere. He is believed to have gone to some western state, probably to Arizona. Mr. STURMER recalls no return visits by EMANUEL with his brother and sister since that time. (u)

During the time that the GREENs have resided at this address they have kept very much to themselves and associate with none of the neighbors. They are ideal tenants, however, since they pay their rent regularly, are quiet and have practically no visitors. (u)

Confidential Informant T-2, of unknown reliability, who is, however, well acquainted in the neighborhood of 7853 S. Essex Avenue, Chicago, advises that he is acquainted with Miss PEARL GREEN and with her brother LOUIS GREEN. He recalls that another brother, name unknown, formerly resided with them but has not been seen in the area for about a year to a year and a half. The informant states, however, that he knows that PEARL GREEN from time to time receives letters and other mail for this brother at the Essex Avenue address and forwards this mail to the brother. He states he does not know the forwarding address, however. (u)

Confidential Informant T-3, another government agency which maintains personnel records, has furnished the following information pertaining to MANUEL GREEN: (u)

MANUEL resided in 1940 at 8138 Saginaw Avenue, Chicago, Illinois. In April of 1942 MANUEL was residing temporarily at 720-59th Place, c/o Kenosha Youth Foundation, Kenosha, Wisconsin, but continued to maintain his permanent address at 8138 Saginaw. (u)

Chicago File 100-21623

In November 1942, MANUEL used the residence address of 1213 N. 44th Street, Milwaukee, Wisconsin. There was some indication, however, that this was a temporary address also and that the Saginaw Avenue address in Chicago continued to be his permanent address. (u)

In December 1945, MANUEL GREEN regarded his permanent address as 7853 S. Essex Avenue, Chicago, Illinois. This was the address to which he went subsequent to his discharge from the U.S. Army. (u)

OCCUPATION:

T-3 advised as follows:

In October 1940, MANUEL GREEN was employed by the Modern Liquor Company, 8449 Burley, Chicago, Illinois. (u)

In November 1941, MANUEL GREEN was working for the War Department, Division of Ordnance Inspection, and was stationed in Milwaukee, Wisconsin. His job was that of Junior Inspector and he inspected Ordnance materials for qualities as to specification. (u)

In December 1941, the informant received the following information from MANUEL GREEN with respect to his previous employment:

Still foreman - 1935-37 - Supervised operation of  
distilling units;

Liquor salesman, 1939-41 - Sold liquor in retail stores;

Newspaper circulation, 1941 - Supervised work of junior  
carriers. (u)

At this time MANUEL GREEN stated that he was best fitted for work as a Chemical Engineer Metallurgist (u)

The headquarters for MANUEL GREEN's employment with the War Department was the Chicago Ordnance District, 38 S. Dearborn, Chicago, Illinois. This was a Civil Service position. On December 4, 1941, the Chicago Ordnance District described MANUEL GREEN's job as the inspection with precision instruments of varied raw metallic metals, mechanical parts, castings, assemblies and components for Ordnance materiel, and the preparation of inspection reports. (u)



Chicago File 100-21623

In April 1942, MANUEL GREEN could be reached through the War Department, Chicago Ordnance District, Milwaukee sub-office, 322 E. Michigan Avenue, Milwaukee, Wisconsin. (u)

In October 1942, GREEN was described by the Chicago Ordnance District as being an Associate Inspector of Ordnance Materiel since October 28, 1941. He was referred to as a skilled employee. His job was further described as that of resident inspector in charge at one of the facilities in the Milwaukee Sub-office area. This involved the inspection of M-40 parachutes. It was also stated that GREEN had had armor plate inspection experience. (u)

The informant learned in December 1942 that as of December 11, 1942, GREEN was no longer employed by the War Department. (u)

During GREEN's service in the U.S. Army, his military occupation specialty was that of optical instrument repair man. (u)

Mr. AL FRAZIN, 9036 S. Commercial, Chicago, who has been acquainted with the GREEN family since about 1920, advised that during the late 1920's and early 1930's EMANUEL GREEN and his brother LOUIS GREEN were employed in the family fruit and vegetable store located on the corner of Commercial and 90th Street, Chicago. Mr. FRAZIN had no information pertaining to subsequent employments of EMANUEL GREEN. EMANUEL is known as Manny, according to FRAZIN. (u)

CITIZENSHIP:

T-3 has furnished the following information which has a bearing on MANUEL GREEN's citizenship:

GREEN was born in Chicago, Illinois, July 25, 1911. In December 1941, GREEN advised the informant that he was a U.S. citizen by birth. (u)

EDUCATION:

T-3 has furnished the following information pertaining to MANUEL GREEN's education:

In December 1941, MANUEL GREEN stated that he had attended eight years of elementary school, four years of high school and had also attended the Crane Junior College, Chicago, for one year taking a General Course. (u)

Chicago File 100-21623

He obtained his B.S. degree in Chemical Engineering after four years attendance at the University of Illinois. He also studied Chemistry for three months at the University of Chicago.

MILITARY RECORD:

T-3 advised as follows:

On October 11, 1942, MANUEL GREEN was given a physical examination in Milwaukee, Wisconsin prior to his being inducted into the Armed Forces of the United States. He was ordered to report for induction on December 17, 1942 at Camp Grant, Illinois. He was inducted through Local Board 13, Chicago, Cook County, Illinois, and was honorably discharged from the Armed Services at Fort Dix, New Jersey, on December 12, 1945. The reason for the discharge was demobilization. GREEN's Army Serial Number was 36-717-782. He used the name of MANUEL GREEN in connection with his Army service. At the time of GREEN's discharge his grade was that of TEC 5 and he was in the Ordnance Division of the U.S. Army. His military occupational specialty was optical instrument repair man. He was in the following battles and campaigns:

Ardennes;  
Central Europe;  
Normandie;  
Northern France;  
Rhineland.

(u)

He received the following decorations and citations:

American Service Medal;  
European - African - Middle Eastern  
Service Medal;  
Good Conduct Medal;  
World War II Victory Medal

(u)

He was not wounded during his time in the Armed Services. He was outside of the United States as follows:

He left the U.S. on February 21, 1944 for the European Theatre of Operations and arrived in ETO February 29, 1945. He left the ETO for the USA November 21, 1945 and arrived in the USA December 4, 1945. (u)

Chicago File 100-21623

GREEN attended no service schools. (u)

FAMILY BACKGROUND:

The September 1949 Directory of the Illinois Bell Telephone Company for Chicago lists a PEARL GREEN, 7853 S. Essex, South Shore 8-3262. (u)

An examination of the mail boxes at 7853 S. Essex Avenue shows that PEARL GREEN occupies Apartment 308. No other names appear for Apartment 308. (u)

Mr. CARL R. STURMER advised that PEARL GREEN resided at that address alone from 1943 until LOUIS and EMANUEL GREEN were discharged from the army in the latter part of 1945 or early part of 1946. (u)

LOUIS GREEN, who is just younger than PEARL GREEN, is presently residing with PEARL and has been since late 1945 or early 1946. He is believed to be an accountant but Mr. STURMER is not certain. He may also have something to do with fruit and vegetables in connection with his employment. His employment is of the type which requires LOUIS to be "dressed up" in connection with his work. (u)

PEARL GREEN is believed to be a teacher of some type and may be connected with the Chicago City Schools. She is believed to teach dancing and physical education. (u)

Both LOUIS and PEARL drive automobiles. The car driven by LOUIS is a 1947 Mercury coupe, 1950 Illinois License No. 184-336. The Automobile License Volumes for 1950, as issued by the Secretary of State for the State of Illinois, lists this license number to L. GREEN, 35 S. Water Market, Chicago, Illinois. It is described as a Mercury, Engine No. 799A1878175. (u)

According to Mr. STURMER, PEARL GREEN drives a 1947 Chevrolet coach, 1950 Illinois License No. 996-014. The Automobile License Volumes previously referred to do not yet include the listing for this number. (u)

T-2 advised that he understands that PEARL GREEN is employed by the Board of Education for the City of Chicago as a dancing and physical education teacher in a school on the South Side. (u)



Chicago File 100-21623

Mr. BEN SACKS, 2453 East 79th Street, operates the Sacks' Meat Market at that address. He advises that he has known PEARL GREEN for about thirteen years. He was also acquainted with PEARL GREEN's mother prior to her death and is aware that PEARL GREEN has two brothers but does not know their names. PEARL GREEN is a teacher in the public schools of the City of Chicago. Mr. SACKS said that although she has traded with him during the entire time that she has resided on South Essex Avenue in Chicago, he has no other information pertaining to Miss GREEN or her family. (u)

Mr. CHARLES W. KENOZER, 6826 S. Stony Island, Chicago, advises that he handled the renting of PEARL GREEN's present apartment to her for his employer, LESLIE M. PRICE, of the same address. Mr. KENOZER furnished the following information:

Miss PEARL GREEN, of 8138 Saginaw Avenue, Chicago, rented a one and one-half room apartment at 7853 S. Essex Avenue, Chicago, on October 1, 1943 and has been a tenant in the same apartment since that date. At the time the apartment was rented Miss GREEN stated that she had been employed by the Board of Education, 228 N. LaSalle Street, Chicago, Illinois, for fourteen years, and directed playground activities at 10347 S. Ewing Avenue, Chicago, Illinois. Her landlord at the time was CHARLES RINGER, 7915 S. Exchange Avenue, Chicago, Illinois. She had resided at the Saginaw Avenue address since 1936. She banked with the South Chicago Savings Bank, Chicago. (u)

Her nearest relative was listed as BEN MEYER, an uncle, 1030 Hyde Park Boulevard, Chicago, Illinois. (u)

The September 1949 Directory of the Illinois Bell Telephone Company for Chicago lists BEN MEYER, 1030 E. Hyde Park, Atlantic 5-1948. (u)

The files of this office contained no information pertaining to MEYER. (u)

Mr. KENOZER stated that he was personally acquainted with the GREENs but did not know them well. He said that PEARL GREEN's two brothers, whose names he does not know, resided with her for several years after World War II and one of them was still residing with her. The other brother is believed to have been married about a year or a year and a half ago and shortly after his marriage left the State of Illinois. Mr. KENOZER said he does not have any information pertaining to the loyalty of Miss GREEN or her brothers. (u)

Chicago File 100-21623

Mr. AL FRAZIN advised that LOUIS GREEN is believed to be an accountant in connection with the fruit and vegetable wholesale business. He says he does not know the name of the firm for which GREEN works. (u)

SAM GREEN was the father of PEARL, LOUIS and EMANUEL GREEN. Sometime about 1925 or shortly thereafter Mr. FRAZIN rented a building to SAM GREEN, which is located on the southwest corner of 90th and Commercial Avenue, Chicago, Illinois. Thereafter SAM GREEN engaged in the fruit and vegetable business on a retail basis at this location for a period of about ten years. The GREENs were moderately successful and the entire family assisted in connection with this business with the exception of PEARL, who continued her schooling and then obtained a position with the Chicago Board of Education sometime about 1930. Mr. and Mrs. SAM GREEN are deceased, according to FRAZIN. (u)

SAM GREEN, for a period of several years, had a partner whose last name was DEMOVSKY. This partner had a son who is presently a dentist located at 9113 Commercial, Chicago, Illinois. (u)

FRAZIN said that he has not been closely associated with the GREENs for about eight years although he continues to be the insurance agent for PEARL GREEN. He said that in all of his dealings with the GREEN family he has noted nothing which would cause him to believe that they are other than loyal to the U.S. He said that he has noted neither Fascist nor Communist tendencies on their part. (u)

Dr. ISIDORE M. DEMOVSKY, 9113 Commercial, advised that he has been acquainted with the GREEN family since the late 1920's. He states that he was formerly the dentist for PEARL, LOUIS and MANUEL GREEN but has not been their dentist now for three or four years. Dr. DEMOVSKY states that he considers that PEARL, LOUIS and MANUEL GREEN are all of the highest character and definitely loyal to the U.S. He advised that he does not know the exact place where LOUIS GREEN is presently employed but believes that it is on South Water Market with some commission house dealing in fruits and vegetables where GREEN works as a bookkeeper. PEARL GREEN is presently employed, according to Dr. DEMOVSKY, by the Board of Education as a physical education and dancing instructor but the exact location of her employment is not known to Dr. DEMOVSKY. (u)

T-3 furnished the following information:

Chicago File 100-21623

MANUEL GREEN has a sister by the name of PEARL GREEN, who in 1940 was residing at the same address as MANUEL, 8138 Saginaw Avenue, Chicago, Illinois. MANUEL also has a brother by the name of LOUIS GREEN. His mother's name was DORA GREEN. (u)

LOUIS GREEN resided at 8138 Saginaw Avenue, Chicago, in 1940. He was born March 25, 1909 at Chicago, Illinois and is a U.S. citizen. His mother was DORA GREEN. In 1940 LOUIS GREEN's employer was Auster - Carl and Company, 51 S. Water Market, Chicago, Illinois. (u)

LOUIS GREEN attended the Crane Junior College for one year studying Commerce. He attended the University of Illinois, Chicago, for one semester studying Commerce. He also attended Northwestern University, Chicago, for four years evenings studying Commerce. In March 1941, LOUIS GREEN stated that his present job included bookkeeping and office management and that he was engaged by a wholesale fruit and vegetable firm. From 1933 to 1935 he was employed in a retail fruit and vegetable store, which he operated. LOUIS GREEN stated he had never been convicted of treason or a felony. (u)

LOUIS GREEN was ordered to report for a physical examination in connection with his possible induction into the Armed Services on February 3, 1942. He was ordered to report for induction in Chicago on February 20, 1942, at which time he was inducted through Camp Grant, Illinois. He was registered with Local Board 13, Chicago, Illinois. (u)

LOUIS GREEN was separated from the service honorably on October 1, 1945 due to demobilization. This took place at Fort Sheridan, Illinois. At the time of his discharge he was a Technical Sergeant in the Army Air Force, ASN 36-320-233. LOUIS GREEN's civilian occupation was accountant. His military occupation was administrative. He was in the following battles:

India - Burma;  
Palembang - Sumatra - Central Burma;  
China;  
Air Offensive - Japan. (u)

He received the following decorations and citations:



Chicago File 100-21623

American Theatre Ribbon;  
Asiatic - Pacific Theatre Ribbon  
with one silver battle star;  
Five overseas service stripes;  
Good Conduct Medal;  
DIST. Unit Badge.

(u)

He was outside the United States as follows:

He left the United States March 26, 1942 for the Asiatic Theatre of Operations arriving there April 3, 1942. He left the ATO June 16, 1943 for the USA arriving here June 25, 1943. He left the USA March 23, 1944 for the Pacific Theatre of Operations arriving there April 23, 1944. He left the PTO September 16, 1945 enroute to the USA arriving here September 21, 1945. (u)

He attended an administrative service school. (u)

T-3 describes LOUIS GREEN as follows:

Name:	LOUIS GREEN
Sex:	Male
Race:	White
Age:	41
Date of birth:	March 25, 1909
Place of Birth:	Chicago, Illinois
Residence:	7853 S. Essex Avenue, Chicago, Illinois
Height:	5'4"
Weight:	135 lbs.
Build:	Short
Hair:	Black
Eyes:	Light brown
Complexion:	Fair
Scars and Marks:	Appendectomy scar
Occupation:	Accountant
Marital status:	Single
Relatives:	
Sister -	PEARL GREEN
Brother -	MANUEL GREEN
Army Serial No.:	36-320-233
Social Security No.:	[REDACTED]

b7c  
(u)

Chicago File 100-21623

The files of the Chicago Office contained no information pertaining to LOUIS or PEARL GREEN. (u)

CREDIT AND CRIMINAL:

Hill's Reports, Inc., a Chicago credit agency, has no information pertaining to EMANUEL GREEN under this name or any other names by which he is known. (u)

The Chicago Police Department has no record pertaining to EMANUEL GREEN under this or any other names by which he is known. (u)

In December 1941, MANUEL GREEN stated, according to T-3, that he had never been convicted of a crime. (u)

MISCELLANEOUS:

Mr. CARL R. STURMER advised that he was acquainted with EMANUEL GREEN but did not know him well. He said that he assumes that EMANUEL is loyal since he never observed anything indicating disloyalty on the part of EMANUEL during the time that EMANUEL occupied the apartment at 7853 S. Essex Avenue with his brother and sister. (u)

Mr. MORRIS TRIFFLER, 7847 Essex Avenue, operates Morry's Delicatessen at that address, which is located in the same building as 7853 S. Essex Avenue. Mr. TRIFFLER advised that he does not specifically recall any of the GREENs. (u)

DESCRIPTION:

The following description was obtained from T-3, AL FRAZIN and CARL STURMER:

Name:	EMANUEL GREEN
aka:	Manuel, Manny
Sex:	Male
Race:	White
Age:	38
Date of Birth:	July 25, 1911
Place of Birth:	Chicago, Illinois
Last known residence:	7853 S. Essex Avenue, Chicago, Illinois

(u)

Chicago File 100-21623

Height:	5'5½"
Weight:	120 lbs.
Build:	Slight
Hair:	Black
Eyes:	Brown
Complexion:	Dark
Scars and Marks:	None known
Occupation:	Trained as Chemical Engineer - Metallurgist
Marital status:	Reported married
Immediate relatives:	
Brother -	LOUIS GREEN
Sister -	PEARL GREEN
Army Serial No.:	36-717-782
Social Security No.:	[REDACTED]

b7c  
(u)

- REFERRED UPON COMPLETION TO THE OFFICE OF ORIGIN -



Chicago File 100-21623

INFORMANT PAGE

62 67 D

T-1 is former Confidential Informant [redacted] identity of agent receiving not known. Information obtained December 18 and 26, 1945. (u)

T-2 is FRED C. LEHMAN, Mail Carrier, South Shore Sub-Station, 2207 E. 75th, who is the carrier for 7853 S. Essex Avenue (Deemed advisable). (u)

T-3 is the Illinois Headquarters, Selective Service System, 523 S. Plymouth Court, Chicago, Illinois. (Information obtained through Mr. ALBERT P. RYDE.) (u)

REFERENCE: Report of Special Agent JOHN R. MURPHY, JR., New York, April 5, 1950. (u)

## Office Memorandum • UNITED STATES GOVERNMENT

TO : Director, FBI

DATE: May 3, 1950

FROM : SAC, New York

SUBJECT: FOOCASE  
ESPIONAGE - R~~TOP SECRET~~

Reference is made to San Francisco letter of 4/21/50 in the case entitled, "UNKNOWN SUBJECT, was; [REDACTED] ETC., ESPIONAGE - R." (TS)

It is noted that the San Francisco letter suggested the possibility that the UNKNOWN SUBJECT, was; [REDACTED] ETC., FUGITIVE American contact may have been connected in some way with either the [REDACTED] (TS) b1

It is further noted that immediately prior to BROTHMAN opening his laboratory in August 1944, apparently [REDACTED] (TS) b1

[REDACTED] (TS) b1  
ARTHUR P. WEBER, former business associate of BROTHMAN, has furnished the following information: (u)

In about August 1943 or possibly later, BROTHMAN and WEBER entered into a contract with Regal Chemical Company, and the Tedlee Chemical Company, both Brooklyn, New York, who were subcontractors to the Bridgeport Brass Company. Regal was engaged in the manufacture of the containers for Aerosol Bombs and BROTHMAN and WEBER, according to WEBER, developed an automatic machine for filling the bombs, as well as a process

cc: 2 Chicago  
2 Indianapolis  
2 New Haven  
San Francisco  
NY 100-95068  
NY 65-15185

RECORDED - 68

INDEXED - 68

JRM:PB  
65-15136

Classified by 2355 WAB/son  
Exempt from GDS, Category 243  
Date of Declassification Indefinite

~~TOP SECRET~~

DATE 6/1/78

APPROPRIATE AGENCIES  
AND FIELD OFFICES  
ADVISED BY ROUTING  
SLIP(S) OF Classification

ALL INFORMATION CONTAINED  
HEREIN IS UNCLASSIFIED  
EXCEPT WHERE SHOWN  
OTHERWISE

CLASSIFIED BY: 3042 PWT/KLS  
DECLASSIFY ON: 1-22-87  
#8-1040

Let To N.Y.  
for immediate  
interview

Brothman & his associates

5-5-50

EVH

11/13/75

26

100-365540-7

MAY 8 1950

5

100-365540-7

Letter to Director, FBI  
NY 65-15136

~~TOP SECRET~~

for making DDT. A disagreement later arose between WEBER and BROTHMAN as to the extent of each others contribution to the so called "BROTHMAN Process". As a result of this disagreement WEBER left the firm, the Chemrugs Design Company, prior to the completion of the contract. WEBER did not know for certain that the contract with Regal, Tedlee and Bridgeport Brass, who were the prime contractors, was completed in about August 1944 or a little later. (u)

During this same period between August 1943 and August 1944, BROTHMAN and WEBER were acting as consulting engineers on a retainer basis for the Graver Tank Company, East Chicago, Indiana. It was WEBER'S opinion, but he could not be certain, that BROTHMAN renewed this contract in his own name with the Graver Tank Company in the Spring or Summer of 1944. As far as WEBER knew all of his and BROTHMAN'S dealings with the Graver Tank Company were with GEORGE MALMGREN, Vice President, and one PRAGER the patent attorney for the firm. WEBER described MALMGREN as in his early fifties; 5' 10-11"; 175 lbs.; heavy set; wears rimless glasses and baking. He said that PRAGER was in his early forties; about 6' tall; slender build; wavy hair; 175 lbs.; smoked a pipe, and gave the appearance of being the college professor type. (u)

In so far as the dealings with the Bridgeport Brass Company were concerned, WEBER knew that prior to the completion of the contract with Bridgeport, Regal, and Tedlee, that BROTHMAN was making an attempt to obtain additional work of an unknown nature to WEBER, through Bridgeport Brass and specifically through one JACK MILLS, whom WEBER described as being a junior sales executive. He described MILLS as being in his late forties; 5' 10-11"; 170-180 lbs.; heavy set; energetic bombastic salesman type of individual with a moustache. WEBER knew of no other individuals with whom BROTHMAN dealt at that time in the Bridgeport Brass Company. (u)

WEBER also stated that the only other firm in the Chicago area with whom he and BROTHMAN had any business dealings was the Chicago Pump Company. He and BROTHMAN had obtained a consulting engineer contract with that firm in 1943 on a one hundred dollars a day fee basis. He could not remember the names of the individuals with whom they dealt, but stated that they were the President and Chief Engineer of the Chicago Pump Company. (u)

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J 5)

~~TOP SECRET.~~



Letter to Director, FBI  
NY 65-15136

~~TOP SECRET~~

It is known from prior interviews with BROTHMAN and WEBER that HENRY A. GOLWYNNE was the President of Chemurgy Design Company, BROTHMAN was the Vice President and WEBER the Secretary. Strictly speaking, therefore, the only partners BROTHMAN had in that enterprise were GOLWYNNE and WEBER. It is a fact that BROTHMAN had difficulty with WEBER, and WEBER has also stated that GOLWYNNE and BROTHMAN did not get along too well since GOLWYNNE was primarily administrator with much less technical knowledge than any of his employees. WEBER has identified the known male employees of Chemurgy as follows:

EMIL BARISH, Mechanical Engineer  
JULES KARCHER, Architect  
OSCAR J. WAGL, Structural Engineer  
ROBERT TOWNSEND, Draftsman

~~KORCHIEN~~  
~~VAGO~~ (u)

He stated that all of these individuals, including TOWNSEND later had gone with BROTHMAN in his new enterprise, which would further indicate that the partners with whom BROTHMAN had difficulty were GOLWYNNE and WEBER. (u)

The Chicago Office is requested to identify the President and Vice President of the Chicago Pump Company and to obtain physical descriptions of them. If their descriptions in any way compare favorably with that of the UNKNOWN SUBJECT, was: [redacted] it is further requested that an effort be made to obtain photographs of them to exhibit to FUCHS and the HEINEMANS. (u) (S) 61

The Indianapolis Office is requested to obtain an accurate physical description of GEORGE MALMGREN, who according to WEBER, has made several trips to New York, and PRAGER the Patent Attorney of the Graver Tank Company. (u)

The New Haven Office is requested to contact an established source at the Bridgeport Brass Company in an effort to learn first the nature of any contracts between that firm and the Regal Chemical Company, the Tedlee Chemical Company and ABE BROTHMAN and associates in 1943, 1944 and 1945. Also if possible JACK MILLS with whom BROTHMAN was dealing in the Bridgeport Brass Company, should be fully identified, a physical description obtain, and if possible a photograph. (u)

It is requested that auxiliary officers afford this matter expeditious attention since the Bureau has requested that BROTHMAN and six of his associates be interviewed in the immediate future. (u)

~~TOP SECRET~~

FEDERAL BUREAU OF INVESTIGATION  
UNITED STATES DEPARTMENT OF JUSTICE

CC-150

To: COMMUNICATIONS SECTION.

Transmit the following message to:

SAC, NEW YORK

May 5, 1950

URGENT

RECORDED

58

100-365040-7

ABRAHAM BROTHMAN, SA., NY-2

REURLET THIRD INSTANT ENTITLED "FOOGARE." INTERVIEWS WITH BROTHMAN  
AND HIS ASSOCIATES SHOULD NOT BE DEFERRED PENDING INVESTIGATION  
REQUERED REFERENCED LETTER. CONDUCT SEPARATE AND SIMULTANEOUS  
INTERVIEWS IMMEDIATELY AND BUREAU AND ATLANTA WHEN INTERVIEWS  
WILL OCCURE.

NYL:dc

HOOVER

ALL INFORMATION CONTAINED  
HEREIN IS UNCLASSIFIED  
DATE 1-22-87 BY 3042/pur/pcl  
#801840

- Mr. Tolson
- Mr. Clegg
- Mr. Glavin
- Mr. Ladd
- Mr. Nichols
- Mr. Rosen
- Mr. Tracy
- Mr. Egan
- Mr. Gurnea
- Mr. Harbo
- Mr. Mohr
- Mr. Pennington
- Mr. Quinn Tamm
- Tele. Room
- Mr. Nease
- Miss Gandy

FEDERAL BUREAU OF INVESTIGATION  
U.S. DEPARTMENT OF JUSTICE  
COMMUNICATIONS SECTION

MAY - 5 1950

TELETYPE

4-26PM

Per del

3 MAY 15 1950  
SENT VIA

UNRECORDED COPY FILED IN 100-58805-1

Federal Bureau of Investigation  
United States Department of Justice  
New York 7, New York

Mr. Tolson	_____
Mr. Ladd	_____
Mr. Clegg	_____
Mr. Glavin	_____
Mr. Nichols	_____
Mr. Rosen	_____
Mr. Tracy	_____
Mr. Harbo	_____
Mr. Belmont	_____
Mr. Mohr	_____
Tele. Room	_____
Mr. Nease	_____
Miss Gandy	_____

~~SECRET~~

May 10, 1950

Director, FBI

Re: ABRAHAM BROTHMAN wa.;  
ESPIONAGE - R

Dear Sir:

ReNYtel, 5/8/50.

Enclosed, herewith, are copies of the articles on Thermal Diffusion and the nine page paper on the subject of Thermal Diffusion, which information was obtained from a highly confidential informant on May 6, 1950.

Encs. (44)

REGISTERED MAIL

Very truly yours,

*Edward Scheidt*  
EDWARD SCHEIDT  
Special Agent in Charge

RECORDED - 34

INDEXED - 34

Classified By 2533-WA/DOH  
Exempt from GDS, Category 252  
Date of Declassification Indefinite

JRM:CS/mcg  
100-95068

~~SECRET~~



## I. Background

A. Definition — Given a mixture of two gases contained between a hot and a cold wall, there will be set up a considerable difference in the relative concentrations of the two gases at the top and the bottom of the apparatus; this effect is known as thermal diffusion (or thermal siphoning). If steady states of temperatures and pressure are continued, then either the separation of the two gases will be complete or an equilibrium will be reached — which equilibrium is determined by a separation factor. If, however, the gas mixture is in motion and small amounts of the products at either or both ends of the equipment are regularly taken off, then by continued repetitions of such a process, a complete separation of almost any two gases may be obtained. But it should be noted that the rate of circulation of the gas mixture must be such that it is well below the critical value for the Reynold's Number, i.e., so that no turbulence will result — otherwise, a considerable amount of re-mixing may occur.

While some difference in the molecular weight of the two gases is helpful in their separation, still pairs of the same molecular weight (i.e.,  $H_2$  and  $He$ ) and even better yet gas pairs containing isotopes (i.e.,  $C^{13}H_4$  and  $CH_4$  or  $HCl^{37}$  and  $HCl^{35}$ ) can

ALL INFO  
HEREIN IS  
DATE 5/5/57

Thermal diffusion in the case of liquids is known as the Soret effect and experimental work on it has been, thus far, confined to a fluid at rest. Not only may solutions of one liquid in the other be separated (i.e., glycerine in water) but also solutions of solids in liquids (sucrose in water) and ternary mixtures ( $H_2O$  -  $HCl$  -  $NaCl_2$ ).

B. Historical — The phenomenon of thermal diffusion was first discovered theoretically by Enskog<sup>1</sup> of Sweden in 1911 and independently by Chapman<sup>2</sup> of England in 1917. Curiously enough it was missed completely by Boltzmann, Van der Waals, Thompson, Maxwell, and the other workers on the kinetic theory of gases. Later in the same year (1917) Chapman and Deetsen<sup>3</sup> gave the first experimental proof of thermal diffusion. It was Chapman<sup>4</sup> who first suggested (1919) the use of thermal diffusion in the separation of isotopes but this idea was ridiculed by Milliken<sup>5</sup> who concluded that it could not compete with the other methods such as centrifugal separation or gaseous diffusion.

As a result, except for such theoretical and experimental work as was done by Chapman up until 1932, the utilisation of thermal diffusion was completely neglected by physicists till 1938 when it was revived by Clusius and Dickel<sup>6</sup> in Germany, and then in America by Brewer and Bramley and a number of other investigators.

The so-called Soret effect for liquids was really first observed by Ludwig<sup>8</sup> in Germany in 1856; it was reported in France by Soret<sup>9</sup> twenty-five years later.

## II. Theory

Furry, Jones, and Onsager<sup>10</sup> (Photocopy 1) believe that "No simple theory can give an account of thermal diffusion; neither its existence nor its sign can be derived from elementary considerations. Its presence can be only understood by a detailed consideration of the equations of transport in a gas." However, Frankel<sup>11</sup> (Photocopy 2) and Gillespie<sup>12</sup> (Photocopy 3) have proposed reasonably simple explanations; these considerations can be used to give a correct estimate of the value of the thermal diffusion constant.

Branley<sup>13</sup> gives as a general description of the three actions that give rise to thermal diffusion:

- a. Difference in mass (thermal or initial diffusion).  
As can be seen in the separation of isotopes, these mass differences need not be very great but it is certain that the splitting up of two gases of widely different molecular weights is a very much more rapid process.
- b. Mass action of gas similar to convection currents.  
This is the origin of the term "thermal streaming".  
The general effect is for the lighter molecules to go to the hot side and rise and for the heavier molecules to go to the cold side and fall, i.e. to



coefficient of thermal diffusion is positive in sign; but for certain mixtures and under certain circumstances this process may be reversed and the sign made negative.

- c. A slight additional concentration exists in the Langmuir film surrounding the hot side -- there is a definite motion of the gas in this film which arises from the swirling motion of the gas outside this film. Thus, an interchange of molecules occurs between the swirls themselves and between them and the Langmuir film due to the differences in mass.

To these may be added:

- d. The radii of the two molecules.

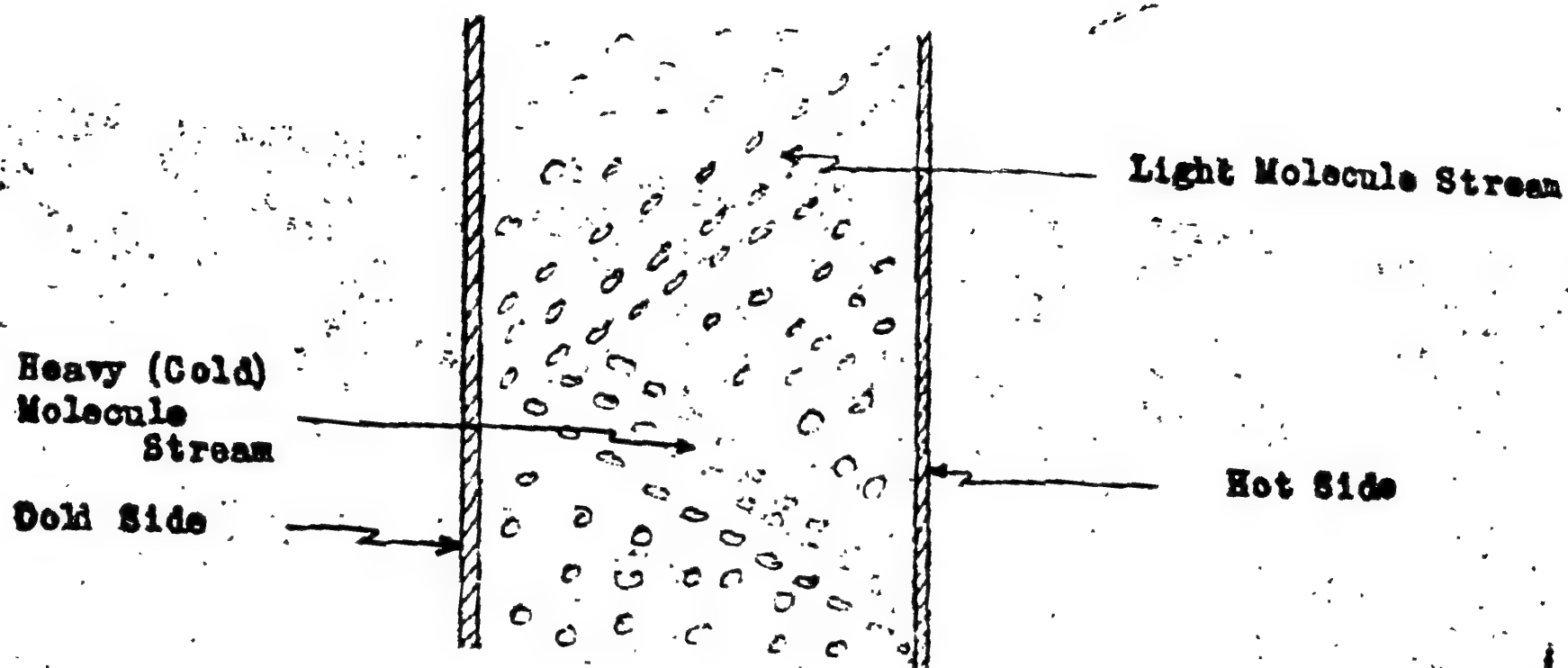
Not all mixtures can be separated as the coefficient of thermal diffusion vanishes when the mode of interaction, the radii and the masses of the two sets of molecules are all equal. Such may be the case<sup>14</sup> for the pair CO and  $N_2$ .

All theoretical efforts to explain the Soret effect in liquids have been completely unsuccessful<sup>15, 16, 17</sup>.

### III. Description of Apparatus

Essentially all that is needed are two concentric cylinders, the inner one heated and the outer one cooled, mounted in a vertical position, with reservoirs at the top and bottom communicating with the annular space between the cylinders where convection and diffusion take place.

The diagram below describes the action taking place in one such device.



As is shown, in most cases the lighter molecules will concentrate toward the top of the apparatus.

Clusius and Dickel<sup>6</sup> ran a heated wire up the axis of a long vertical hollow tube into which was put the gas mixture to be separated; using such an apparatus and a 50% Helium - 50% Bromine mixture, the two gases can be separated in a matter of minutes in a tube only 3 feet long. Korsching, Wirtz and Masch<sup>18</sup> describe also a flat metal form of thermal diffusion equipment in addition to the two already given. Taylor and Geckler<sup>19</sup> (Photocopy 4) and Nier and Bardeen<sup>20</sup> (Photocopy 5) detail the construction of thermal diffusion

columns used in this country for isotopic separation. The use of a rotating annular space apparatus to increase the field of gravity by a factor up to 10 has been tried by Farber and Libby<sup>21</sup> (Photocopy 6) and with interesting results.

Devices for thermal diffusion in liquids are described by Gillespie and Breck<sup>22</sup> (Photocopy 7) and by Carr<sup>23, 24</sup> (Photocopy 8 and 9) Gillespie and Breck use glass apparatus and an annular space of circular shape while Carr utilizes the flat shallow groove form after Korsching and Wirtz<sup>25</sup>; in this last respect it should be noted that the apparatus works best when sloped at a definite angle.

Getting back to thermal diffusion in gases, one very significant feature of the apparatus is that an annular spacing of 0.7 cm. seems to work better than any other distance. Also, once the preliminary work on the separation factor, , for any mixture of two gases has been done, the equations of Furry, Jones and Onsager<sup>10</sup> (Photocopy 1) can be used to aid in the design of apparatus.

While in most of the reported work the inner tube is usually heated by Nichrome wire still any other means, such as steam or Bothern can probably be used much more effectively on an industrial scale.

#### IV. Uses of Thermal Diffusion

It is proposed to utilize thermal diffusion to increase the concentration of  $O_2$  in air from the normal 21% up to 60%



er 80%. This enriched oxygen can then be used for any oxidation process such as the manufacture of sulfuric acid from sulfur and the preparation of nitric acid from ammonia. The saving in size of equipment, power, and overall efficiency would be incalculable.

Other proposed fields of investigation would be:

- a. Recovery of  $\text{CO}_2$  from stack gases: if the ordinary 14% by volume  $\text{CO}_2$  concentration could be raised to say 40% or 60%, then this process can be made feasible, i.e., chemical means of absorbing the  $\text{CO}_2$  could then be employed.
- b. Separation of azeotropic liquid mixtures particularly such as ethanol-water and the bothersome methanol-other solvents azeotropes.
- c. Separation of liquid mixtures with close boiling points such as the xylols.
- d. Concentration of the end products of the butanol-acetone-ethanol fermentation. These occur in a total of only 2 to 2 grams of solvent per 100 cc. of beer and the cost of distillation is necessarily high.
- e. Separation of fog from gases.
- f. Separation of traces of impurities from liquids, such as thiophene in benzene.
- g. Separation of isosteric and isomeric mixtures.

This list is only a hint as to what can actually be done by the application of thermal diffusion.

## V. Conclusions

While nothing as yet has appeared in the literature regarding the application of thermal diffusion to an industrial process, still, in order to be on the safe side it must be assumed that such work is being investigated. It is certain, however, that the first person to submit pilot plant proofs of definite industrial uses will be in a key position in a new and potentially vast field. Given a particular design of apparatus for application to a particular separation such an apparatus and process could easily be patented; and, given a sufficient head start, a whole patent structure could be built up.

Note: Appended are the nine photocopies referred to in the body of the report.

## References

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INTERNAL SECURITY

## I. Background

A. Definition -- Given a mixture of two gases contained between a hot and a cold wall, there will be set up a considerable difference in the relative concentrations of the two gases at the top and the bottom of the apparatus; this effect is known as thermal diffusion (or thermal siphoning). If steady states of temperatures and pressure are continued, then either the separation of the two gases will be complete or an equilibrium will be reached -- which equilibrium is determined by a separation factor. If, however, the gas mixture is in motion and small amounts of the products at either or both ends of the equipment are regularly taken off, then by continued repetitions of such a process, a complete separation of almost any two gases may be obtained. But it should be noted that the rate of circulation of the gas mixture must be such that it is well below the critical value for the Reynold's Number, i.e., so that no turbulence will result -- otherwise, a considerable amount of re-mixing may occur.

While some difference in the molecular weight of the two gases is helpful in their separation, still gas pairs of the same molecular weight (i.e.,  $N_2$  and  $C_2H_4$ ) and even better yet gas pairs containing isotopic elements (i.e.,  $C^{13}H_4$  and  $CH_4$  or  $HCl^{37}$  and  $HCl^{35}$ ) can be split.

Thermal diffusion in the case of liquids is known as the Soret effect and experimental work on it has been, thus far, confined to a fluid at rest. Not only may solutions of one liquid in the other be separated (i.e., glycerine in water) but also solutions of solids in liquids (sucrose in water) and ternary mixtures ( $H_2O - HCl - BaCl_2$ ).

- B. Historical -- The phenomenon of thermal diffusion was first discovered theoretically by Enskog<sup>1</sup> of Sweden in 1911 and independently by Chapman<sup>2</sup> of England in 1917. Curiously enough it was missed completely by Boltzmann, Van der Waals, Thompson, Maxwell, and the other workers on the kinetic theory of gases. Later in the same year (1917) Chapman and Bootson<sup>3</sup> gave the first experimental proof of thermal diffusion. It was Chapman<sup>4</sup> who first suggested (1919) the use of thermal diffusion in the separation of isotopes but this idea was ridiculed by Mulliken<sup>5</sup> who concluded that it could not compete with the other methods such as centrifugal separation or gaseous diffusion.

As a result, except for such theoretical and experimental work as was done by Chapman up until 1932, the utilization of thermal diffusion was completely neglected by physicists till 1938 when it was revived by Clusius and Lickel<sup>6</sup> in Germany, and then in America by Brewer and Bramley and a number of other investigators.



The so-called Soret effect for liquids was really first observed by Ludwig<sup>8</sup> in Germany in 1856; it was reported in France by Soret<sup>9</sup> twenty-five years later.

## II. Theory

Furry, Jones, and Onsager<sup>10</sup> (Photocopy 1) believe that "No simple theory can give an account of thermal diffusion; neither its existence nor its sign can be derived from elementary considerations. Its presence can be only understood by a detailed consideration of the equations of transport in a gas." However, Frankel<sup>11</sup> (Photocopy 2) and Gillespie<sup>12</sup> (Photocopy 3) have proposed reasonably simple explanations; these considerations can be used to give a correct estimate of the value of the thermal diffusion constant.

Branley<sup>13</sup> gives as a general description of the three actions that give rise to thermal diffusion:

a. Difference in mass (thermal or initial diffusion).

As can be seen in the separation of isotopes, these mass differences need not be very great but it is certain that the splitting up of two gases of widely different molecular weights is a very much more rapid process.

b. Mass action of gas similar to convection current.

This is the origin of the term "thermal siphoning". The general effect is for the lighter molecules to go to the hot side and rise and for the heavier molecules to go to the cold side and fall, i.e., the

coefficient of thermal diffusion is positive in sign; but for certain mixtures and under certain circumstances this process may be reversed and the sign made negative.

- c. A slight additional concentration exists in the Langmuir film surrounding the hot side -- there is a definite motion of the gas in this film which arises from the swirling motion of the gas outside this film. Thus, an interchange of molecules occurs between the swirls themselves and between them and the Langmuir film due to the differences in mass.

To these may be added:

- d. The radii of the two molecules.

Not all mixtures can be separated as the coefficient of thermal diffusion vanishes when the mode of interaction, the radii and the masses of the two sets of molecules are all equal. Such may be the case<sup>14</sup> for the pair CO and N<sub>2</sub>.

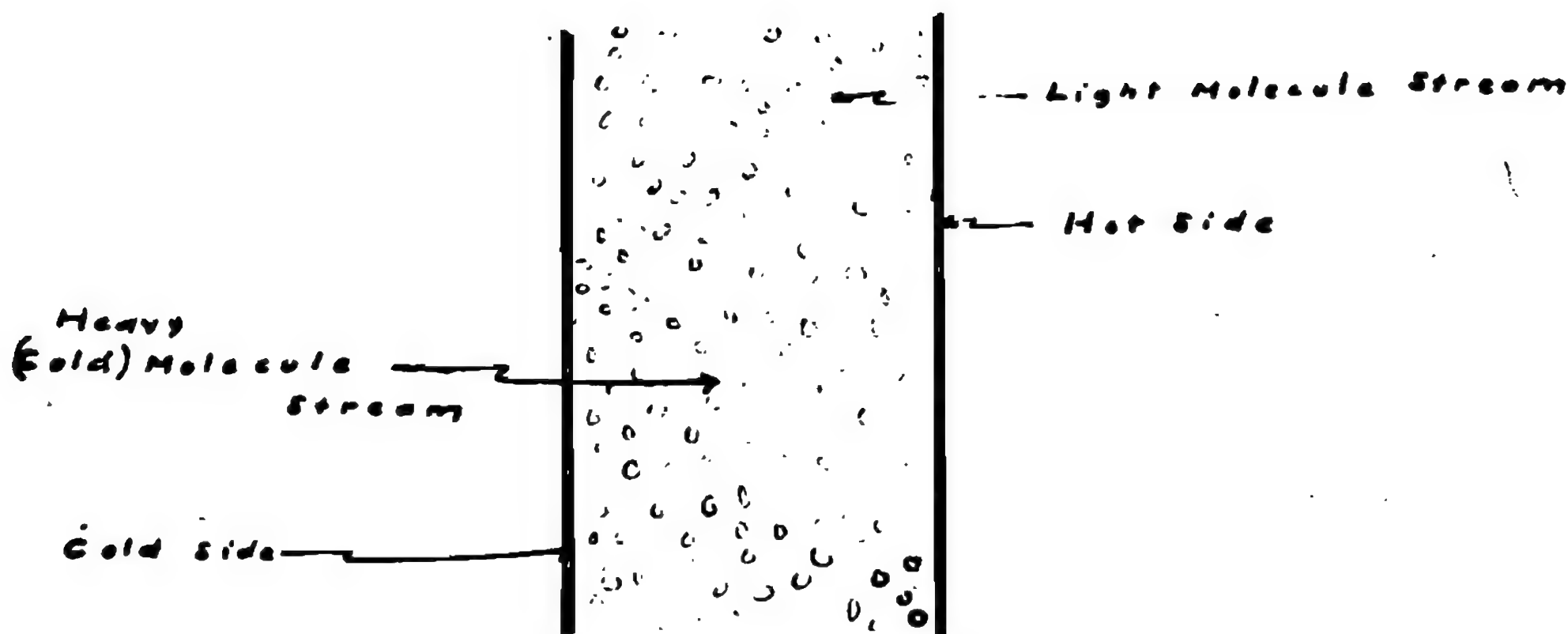
All theoretical efforts to explain the Soret effect in liquids have been completely unsuccessful<sup>15, 16, 17</sup>.

### III. Description of Apparatus

Essentially all that is needed are two concentric cylinders, the inner one heated and the outer one cooled, mounted in a vertical position, with reservoirs at the top and bottom communicating with the annular space between the cylinders where convection and diffusion take place.

- 5 -

The diagram below describes the action taking place in one such device.



As is shown, in most cases the lighter molecules will concentrate toward the top of the apparatus.

Chusius and Dickel<sup>6</sup> ran a heated wire up the axis of a long vertical hollow tube into which was put the gas mixture to be separated; using such an apparatus and a 50% Helium - 50% Bromine mixture, the two gases can be separated in a matter of minutes in a tube only 3 feet long. Korsching, Wirty and Masch<sup>18</sup> describe also a flat metal form of thermal diffusion equipment in addition to the two already given. Taylor and Gockler<sup>19</sup> (Photocopy 4) and Nier and Bardeen<sup>20</sup> (Photocopy 5) detail the construction of thermal diffusion



columns used in this country for isotopic separation. The use of a rotating annular space apparatus to increase the field of gravity by a factor up to 10 has been tried by Farber and Libby<sup>21</sup> (Photocopy 6) and with interesting results.

Devices for thermal diffusion in liquids are described by Gillespie and Breck<sup>22</sup> (Photocopy 7) and by Carr<sup>23, 24</sup> (Photocopies 8 and 9). Gillespie and Breck use glass apparatus and an annular space of circular shape while Carr utilizes the flat shallow groove form after Korsching and Wirty<sup>25</sup>; in this last respect it should be noted that the apparatus works best when sloped at a definite angle.

Getting back to thermal diffusion in gases, one very significant feature of the apparatus is that an annular spacing of 0.7 cm. seems to work better than any other distance. Also, once the preliminary work on the separation factor, , for any mixture of two gases has been done, the equations of Furry, Jones and Onsager<sup>10</sup> (Photocopy 1) can be used to aid in the design of apparatus.

While in most of the reported work the inner tube is usually heated by Nichrome wire still any other means, such as steam or Dowtherm can probably be used much more effectively on an industrial scale.

#### IV. Uses of Thermal Diffusion

It is proposed to utilize thermal diffusion to increase the concentration of  $O_2$  in air from the normal 21% up to 60%

or 80%. This enriched oxygen can then be used for any oxidation process such as the manufacture of sulfuric acid from sulfur and the preparation of nitric acid from ammonia. The saving in size of equipment, power, and overall efficiency would be incalculable.

Other proposed fields of investigation would be:

- a. Recovery of  $\text{CO}_2$  from stack gases: if the ordinary 14% by volume  $\text{CO}_2$  concentration could be raised to say 40% or 60%, then this process can be made feasible, i.e., chemical means of absorbing the  $\text{CO}_2$  could then be employed.
- b. Separation of azeotropic liquid mixtures particularly such as ethanol-water and the bothersome methanol-other solvents azeotrope.
- c. Separation of liquid mixtures with close boiling points such as the xylols.
- d. Concentration of the end products of the butanol-acetone-ethanol fermentation. These occur in a total of only 2 to 3 grams of solvent per 100 cc. of beer and the cost of distillation is necessarily high.
- e. Separation of fog from gases.
- f. Separation of traces of impurities from liquids, such as thiophene in benzene.
- g. Separation of isosteric and isomeric mixtures.

This list is only a hint as to what can actually be done by the application of thermal diffusion.

## V. Conclusions

While nothing as yet has appeared in the literature regarding the application of thermal diffusion to an industrial process, still, in order to be on the safe side it must be assumed that such work is being investigated. It is certain, however, that the first person to submit pilot plant proofs of definite industrial uses will be in a key position in a new and potentially vast field. Given a particular design of apparatus for application to a particular separation such an apparatus and process could easily be patented; and, given a sufficient head start, a whole patent structure could be built up.

Note: Appended are the nine photocopies referred to in the body of the report.

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## Letters to the Editor

PROMPT publication of brief reports of important discoveries in physics may be secured by addressing them to this department. The closing date for this department is the third of the month. Because of the late closing date for the section no proof can be shown to authors. The Board of Editors does not hold itself responsible for the opinions expressed by the correspondents. Communication should not in general exceed 600 words in length.

## Depolarization of Raman Lines

## A Further Simplification of Method

GEO. GLOCKER, JOHN F. HUCK, AND LEON C. PATTERSON  
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June 9, 1944

GLOCKER and Baker<sup>1</sup> have studied the use of Polaroid in the measurement of the depolarization factors of Raman lines. They used a mica plate in order to rotate one of the components following the method of Stitt and Vost.<sup>2</sup> Lately we have realized that the mica half wave plate is unnecessary if the two Polaroid films are positioned in front of the spectrograph so that their line of contact is at 45° to the vertical axis of the spectrograph. Preliminary results seem to show that this method will work satisfactorily. This suggested arrangement is published now because further work will be delayed for an unknown period on account of the war.

<sup>1</sup>Geo. Glocker and H. T. Baker, J. Chem. Phys. 11, 446 (1943).  
<sup>2</sup>F. Stitt and D. M. Vost, J. Chem. Phys. 5, 386 (1937).

## Thermal Diffusion in Liquids

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July 12, 1944

A THERMAL diffusion tube similar to that described by Korsching and Wirtz<sup>1</sup> has been used to observe

TABLE I

Molar concentration of ZnSO <sub>4</sub>	Time in hours	Tube slope in degrees	$C_b/C_t$
0.6	2	45	3.70
0.6	4	45	4.97
0.6	8	45	10.8
0.6	12	45	17.1
0.4	2	45	3.04
0.6	2	45	3.70
0.8	2	45	2.85
0.6	2	0	2.55
0.6	2	15	2.87
0.6	2	30	3.28
0.6	2	45	3.70
0.6	2	60	3.62
0.6	2	75	3.09
0.6	2	85	2.71

effects obtainable by varying some of the parameters involved in thermal diffusion experiments.

The tube, formed by clamping a rectangular Phofilm gasket between two brass strips, has been previously described.<sup>2</sup> Since difficulty was encountered in keeping the



FIG. 1



FIG. 2

tube liquid tight with a 100 gauge Phofilm gasket, 450 gauge Phofilm was substituted. The diffusion column thus formed was rectangular in cross section, 1.59 x 0.057 cm, and 1 meter long. The average temperature difference  $\Delta T$  maintained between the top and bottom sides of the tube was 40°C.

Solutions of ZnSO<sub>4</sub> were used throughout the investigation since they had been previously shown to give a large effect.<sup>1</sup> Analyses of concentration were made by measurement of the refractive index.

The results are given in Table I. The effected separation is expressed as the ratio of the molar concentration  $C_b$  of a sample taken from the bottom of the tube to the concentration  $C_t$  of a sample from the top.

Figures 1 and 2 are graphs of data taken from Table I. They show more clearly the maxima obtained.

<sup>1</sup>Korsching and Wirtz, Naturwiss. 27, 367 (1930).

<sup>2</sup>H. Carr, Phys. Rev. 61, 726A (1942).

<sup>3</sup>Kindly supplied by the Goodyear Rubber Company, Akron, Ohio.

## Thermal Diffusion in Ternary Liquid Mixtures, Particularly Aqueous Solutions Containing Ferrous Chloride\*

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(Received August 5, 1940)

The accumulative arrangement of Clusius and Dickel for thermal diffusion was used to study the concentration changes at the extreme ends of the apparatus that occur in various mixtures, particularly solutions of two solutes in water. The apparatus gave reasonably reproducible results. To avoid uncertainties due to creeping along the upper part of the hot wall, any apparatus intended for the study of slightly soluble substances should be designed, as was the apparatus used, so that it can be filled without leaving an air space between hot and cold wall. The enrichment of acetic acid in water solution at the cold (and lower) end is rather small, compared with that of glycerine, or many salts or strong acids. Addition of sodium acetate does not greatly affect the enrichment of acetic acid. The enrichment of ferrous chloride in water at the cold end is

considerable, but in the presence of 1M HCl the enrichment occurs at the hot end. In the presence of 1N  $H_2SO_4$  the enrichment was zero. The case is opposite with zinc chloride. Here the small cold end enrichment that occurs in the presence of a trace of acid to prevent hydrolysis is considerably increased in the presence of 1M HCl. In a solution of ferric chloride and 1M HCl the enrichment of iron was also at the hot end. Hydrolysis takes place, but this probably works against such a result. It appears that a heavy constituent of a ternary liquid solution can migrate from cold to hot end against the direction normally expected. A simple function of the composition is given whose sign is the same as the sign of the enrichment at the cold end in all binary mixtures (liquid or gaseous) so far studied, but not always the same in ternary mixtures.

### INTRODUCTION

THE arrangement of Clusius and Dickel<sup>1</sup> for producing separation by thermal diffusion works by combination of thermal diffusion along a horizontal thermal gradient between two vertical walls and convection along these walls. The arrangement used by various investigators of the Soret effect utilizes a vertical thermal gradient, the higher temperature being maintained above in order to avoid convection.

The arrangement of Clusius and Dickel may be regarded as a means for multiplying the Soret effect and offers a sensitive means of studying it. Unfortunately the factor by which the Soret effect is multiplied is not readily determinable, so that interpretation in terms of Soret effect can be only semiquantitative. Nevertheless, we have tried to investigate the behavior of some ternary mixtures containing water and two solutes, with respect primarily to the question whether the behavior of each of the solutes is independent.

### APPARATUS

The arrangement was used in the form of two concentric glass tubes, steam being passed

through the inner, and cooling water through the outer, the solution under investigation being in the annular space between the two tubes. Brewer and Bramley<sup>2</sup> have used this form. The Pyrex diffusion apparatus is shown in Fig. 1. The tubes for enclosing the annular space were selected as the best pair from about 100 samples and built into apparatus No. 1. The width of the annular space (along a radius) is about 0.75 mm, the total length about 1 meter and the capacity of annular space plus dead space at top and bottom about 71 cc. The next best pair of tubes was built into apparatus No. 2. The width of annular space is about 1.25 mm, the length 1 meter and the capacity about 85 cc. Apparatus No. 2 gave considerably smaller separations in every solution used for comparison and only a few experiments are here reported with it.

In July the cooling water entered (the bottom) at 20° and left at 32°, constant to about 0.5° for days. This would make the mean temperature difference of the outside surfaces of the walls 100–26 or 74°. In winter this difference increased to 80° and rarely 85°.

Some preliminary experiments with 10 percent (by weight) of glycerine showed with neither

\* Contribution No. 463 from the Research Laboratory of Physical Chemistry. This is principally based on the thesis presented by Mr. Breck for the B.S. degree.

<sup>1</sup> K. Clusius and G. Dickel, *Naturwissenschaften*, 26, 546 (1938).

<sup>2</sup> A. K. Brewer and A. Bramley, *Phys. Rev.* 55, 590 (1939).



the decrease in pressure of the He caused by the cooling, it was possible to reproduce the analyses to within one percent.

The He-CO<sub>2</sub> gas used was mixed in a pressure cylinder at several atmospheres pressure and introduced into the apparatus at atmospheric pressure. The air was removed by flushing with excess of the gas. It was not possible to evacuate the wheel because the walls were too thin to support atmospheric pressure.

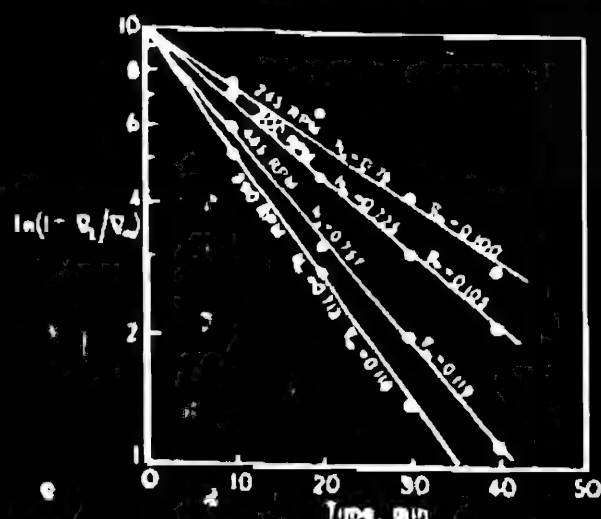


FIG. 2. Separation vs. time at various speeds of rotation.  $\Delta T = 290^\circ\text{C}$ , heater area =  $278\text{ cm}^2$ .

### RESULTS

#### Separation vs. time

Figure 2 presents data obtained with the hot plate at  $340^\circ\text{C}$  and the cold plate at  $50^\circ\text{C}$ , the wheel rotating at various speeds and the initial composition of the gas having various values. The ordinates are logarithms of one minus the ratio of the separation at any given time to that for the equilibrium state. The separations,  $\Delta_i$ , were calculated as the difference between the mole fraction,  $N$ , of He at the rim or the axis and the initial mole fraction,  $N_0$ . A typical set of data is given in Table I. The data seem to justify approximately the exponential expression

$$\Delta_i = \Delta_0(1 - e^{-\lambda t}) \quad (1)$$

TABLE I. Separation vs. time. 485 r.p.m.,  $\Delta T = 290^\circ$ ,  $\Delta_0(\text{center}) = 0.119$ ,  $N_0 = 0.757$ .

Time (min)	0	10	20	30	40	50
$1 - \frac{\Delta_i}{\Delta_0}$	1	0.60	0.32	0.20	0.11	

for the dependence of the separation on the time,  $\Delta_i$  being the separation at any given time  $t$ ,  $\Delta_0$  the equilibrium separation, and  $\lambda$  a constant measuring the rate of separation. Figure 3 presents the data for the effect of variation of the temperature gradient on the rate of separation,  $\lambda$ . Figure 4 shows the variation of the rate,  $\lambda$ , with r.p.m. A rather sudden break occurs at about 400 r.p.m. The main point about these data is the approximately linear rise in the rate with the square of the speed of rotation,  $\omega^2$ , until the break occurs.

Figure 5 shows a similar set of data for the variation of the equilibrium separation,  $\Delta_0$  (center) with  $\omega^2$ . Here also, an approximately linear rise occurs till  $\omega$  becomes approximately 400 r.p.m. Figure 6 presents the data for the variation of  $\Delta_0$  (center) with the temperature difference. Figure 7 shows the  $\Delta_0$  (center) vs.  $\omega^2$  for two heaters the larger having an area of  $435\text{ cm}^2$  and the smaller having  $278\text{ cm}^2$  proving that the heater area had no serious effect on the speed at which the linear rise in  $\Delta_0$  (center)

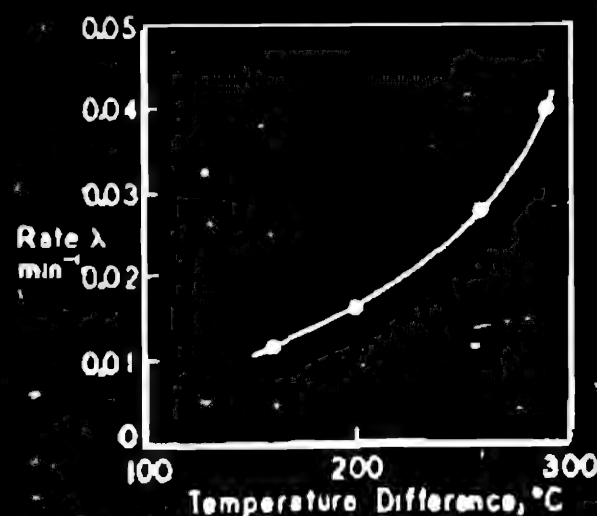


FIG. 3. Rate of separation vs. temperature difference.

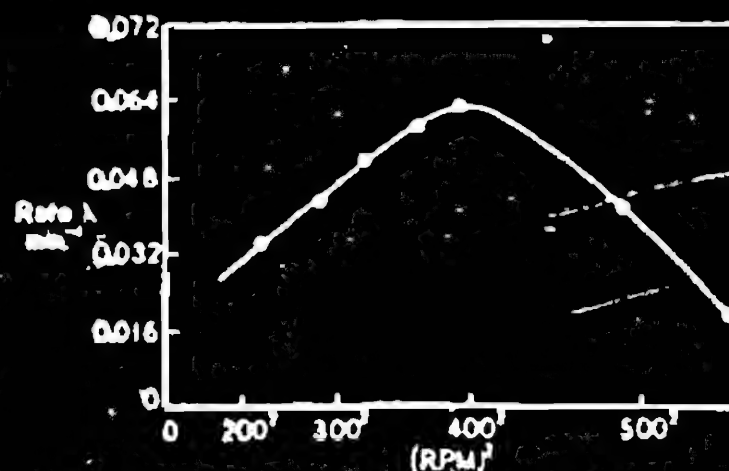


FIG. 4. Rate of separation vs. speed of rotation.

apparatus any difference with time from 22 to 23 hours. In later experiments a comparison of results for different lengths of time was often possible and there was no indication that more than 24 hours was required for the steady state, unless possibly in some solutions containing three solutes.

#### FILLING THE APPARATUS

For all the experiments but the last three the annular space was filled so that the solution stood during the experiment at about the level of the cooling water. This left a small air space above the liquid. The upper filling tube was closed with a glass cap and was after the steady temperature was reached. This prevented evaporation or oxidation.

The air space allowed salts to creep up along the hot wall. There the liquid film evaporated, the solvent passing to the cold wall. With solutions containing  $\text{BaCl}_2$  creeping was very considerable and the results are not stressed. In the case of the other salts (except  $\text{ZnCl}_2$ ) creeping occurred, but to a very small extent—the deposit was estimated to amount to not more than 0.1 gram. The rate at which the fluid is circulated along the walls is very considerable and it would seem that the small loss of material should occur at the expense of both hot and cold ends of the tube, without particular prejudice to either.

Nevertheless, the results for ferrous chloride in mixtures were so unexpected that three experiments (here reported as the last three items of Table I) were done after the completion of all the other work, when we found that the apparatus can be filled so that no air space is in contact with the hot wall and creeping is therefore prevented. Since the volume of the upper dead space is considerably greater by this manner of filling, a longer time was allowed for diffusion to take place.

#### SAMPLING

After the diffusion, a sample of about 1 cc was taken from the top with a small capillary pipette. When cool, a portion of about 0.3 cc was accurately measured in a special pipette. A sample of about 1 cc was taken from the

bottom after wasting 6 drops to clear the stopcock leads. In each of the last three experiments of Table I about 1.5 cc was taken and 1 cc used for analysis. Samples from the middle were sometimes taken with a long capillary pipette and sometimes through the stopcock after discarding a large portion. When the transfer of component is small, the middle portion agrees in composition with the original solution used for filling and was often taken as a measure of it.



FIG. 1. Diffusion apparatus. A cork stopper was actually used in stead of the higher of the two ring seals, but it requires frequent replacement, because of the action of the steam.

In the case of solutions containing  $\text{HCl}$  and  $\text{FeCl}_2$  that diffused for 4 days, samples from levels one-third down the tube and two-thirds down showed large changes of acidity from the original, and the original titer was used as a basis. The titers for ferrous iron from these levels gave a welcome check on the titer of the original mixture.

#### ANALYSIS

Measurements of refractive index were used for solutions of glycerine and of acetic acid, as noted below.

In solutions containing iron, ferrous iron was determined by permanganate titration. Since chloride was present the method was checked by analysis of known mixtures. Ferric iron was determined from the titer for ferrous iron and the titer for total iron as found after reduction with  $\text{SO}_2$  and removal of excess  $\text{SO}_2$ . In mixtures of  $\text{FeCl}_2$  and  $\text{HCl}$  the acid was first determined



by titration with sodium carbonate in the presence of bromphenolblue (without any precipitation of iron) and the ferrous iron then determined by permanganate in the same sample, a stream of nitrogen being used throughout to prevent oxidation. In mixtures containing ferric iron the acidity was not determined.

In the analysis of mixtures of  $\text{ZnCl}_2$  (or  $\text{BaCl}_2$ ) and  $\text{HCl}$  the hydrogen ion was first titrated in the presence of methyl red. The

TABLE I. Diffusion of solutions containing  $\text{HCl}$ ,  $\text{FeCl}_3$ , or  $\text{FeCl}_2$  or combinations in apparatus No. 1

APPROX. COMPOSITION OF SOLUTION	HOURS	COMP. SENT	PER CENT EFFECT	TITER RATIO, COUL. HOU. VS. H.
1M $\text{HCl}$	41	$\text{H}^+$	160	9.4
0.5M $\text{FeCl}_3$	23	$\text{Fe}^{3+}$	22	1.29
Same	31	$\text{Fe}^{3+}$	21	1.30
Same	24	$\text{Fe}^{3+}$	25	1.32
1M $\text{HCl}$ , 0.5M $\text{FeCl}_3$	20	$\text{Fe}^{3+}$	-10	0.90
Same	23	$\text{Fe}^{3+}$	-5	0.95
0.5M $\text{H}_2\text{SO}_4$ , 0.5M $\text{FeCl}_3$	25	$\text{H}^+$	190	39
1M $\text{HCl}$ , 0.5M $\text{BaCl}_2$	24	$\text{Ba}^{2+}$	122	5.0
1M $\text{HCl}$ , 0.5M $\text{ZnCl}_2$	20	$\text{H}^+$	44	1.64
0.01M $\text{HCl}$ , 0.5M $\text{ZnCl}_2$	20	$\text{H}^+$	106	3.9
1M $\text{HCl}$ , 0.453M $\text{FeCl}_2$	4 x 24	$\text{Fe}^{2+}$	30	1.37
Same	4 x 24	$\text{Fe}^{2+}$	100	3.7
0.5M $\text{FeCl}_3$	4 x 24	$\text{Fe}^{3+}$	4	1.04
	4 x 24	$\text{H}^+$	-13	0.88
	4 x 24	$\text{Fe}^{3+}$	>180	>19
	4 x 24	$\text{H}^+$	-11	0.89
	4 x 24	$\text{Fe}^{3+}$	194	20
	4 x 24	$\text{Fe}^{3+}$	22	1.27

total chloride was then determined by titration with 0.1N  $\text{AgNO}_3$  in the presence of fluorescein as adsorption indicator, and the  $\text{Zn}$  (or  $\text{Ba}$ ) obtained by difference. When the method was checked by analysis of solutions of  $\text{HCl}$  a small difference of titer was found ( $\text{H}$  and  $\text{Cl}$ ). The difference was applied as a correction factor to the results for mixtures of  $\text{ZnCl}_2$  (or  $\text{BaCl}_2$ ) and  $\text{HCl}$  in order to get the best possible relative accuracy for total chloride.

#### EXPRESSION OF RESULTS

It will be noted that we do not attempt to determine the total transfer of component past some horizontal plane, but only the extremes of concentration at the two ends of the apparatus. The "percent effect" we define to be the titer of the sample from the lower end minus the titer from the upper end, the difference being then

multiplied by 100 and divided by the titer of the original sample subjected to diffusion. When the result is negative, this means that the substance is (abnormally) enriched at the upper end.

No "correction" was applied for changes in the average temperature ( $74-85^\circ$ , according to the season of the year). The results which we compare were done under nearly the same conditions.

The concentration ratio—lower titer divided by upper—is also of some interest and is reported in Tables I and II. It is not possible to calculate it accurately from the percent effect alone because the mean of the compositions, upper and lower, is often not equal to the original or middle composition.

#### RESULTS

In apparatus No. 2 a 10-percent (by weight) solution of glycerine in water was subjected to diffusion and the solutions analyzed by the refractive index. The percent effect was 6.44. Samples at 22 and 48 hours showed no difference. Repetition of the experiment gave in 22 hours the percent effect 6.54.

In apparatus No. 1 the same solution showed an effect of 28.8 percent, with no differences in the results at 20, 28 and at 41 hours. A repetition of the experiment gave 35 percent in 22.5 hours.

In apparatus No. 2 a 50-percent solution of glycerine in water showed an effect of 3 percent in 18 hours.

A solution of 62 percent (by weight) acetic acid in water showed no effect by refractive index in either apparatus in 45 hours.

A more dilute solution of acetic acid—10 percent and about 1.7 molal—showed in apparatus No. 1 an effect of 8.1 percent in 22.5 hours, and on repetition an effect of 10 percent in 20.3 hours.

Various mixtures of acetic acid and sodium acetate were prepared and subjected to diffusion in apparatus No. 1. The effect for sodium acetate was determined by the refractive index. A small correction for the refraction of the acetic acid was applied which ignored possible small changes in its concentration. Table II shows the composition of the original solution and the percent effect for sodium acetate. The



transfer of acetic acid was shown to be small or zero by measuring the pH of the various samples by means of a glass electrode and by then comparing the observed pH with that calculated from the measured concentration of acetate in the sample together with the concentration of acetic acid it would have, were there no transfer of acetic acid. The approximate agreement between observed and calculated pH was satisfactory and showed that the transfer of acetic acid is small in the solutions containing sodium acetate.

These results are not sufficient to establish that the acid and the salt in this case diffuse independently but it is very probable that they do so at least approximately.

More interesting results were seen when solutions containing iron chloride were subjected to diffusion. Ferric chloride in water is hydrolyzed at once along the hot wall. This is due to the extensive migration of HCl (formed by hydrolysis) from hot to cold. Ferrous chloride is not hydrolyzed in our apparatus if oxidation is entirely prevented. This is accomplished by leaving a trace of  $\text{SO}_2$  in the solution until the apparatus is filled in a stream of nitrogen. When all the  $\text{SO}_2$  was, on the other hand, removed by boiling in a stream of nitrogen and the filling occurred in a stream of nitrogen, a little oxidation took place and a light yellow film was deposited on the upper part of the hot wall. The results for transfer of ferrous iron were substantially the same whether this occurred or not, as is shown by the second item of Table I compared with the next two. In the case of the second item there was a slight film. In the next two, and in all further cases (except the last item) in which ferrous chloride was present without ferric, the trace of  $\text{SO}_2$  prevented any film formation. In the case of the last item the  $\text{SO}_2$  was probably too successfully removed in the apparatus by allowing the uppermost part to come momentarily to boiling under partial vacuum after the steam had been on for an hour, and a thin metallic-looking film was formed along the upper third of the hot wall. The result of this experiment agrees with the others.

When solutions containing ferric chloride and HCl (1M) are subjected to diffusion, hydrolysis still takes place on the hot wall, a crust forming

on its upper part. Portions of the crust occasionally drop loose and fall to the bottom, where they perhaps redissolve in part in the strong HCl (about 2M). The hydrolysis makes, therefore, the interpretation of the results somewhat uncertain, but any enrichment observed at the lower end is presumably too high. Thus when negative enrichments are found they are probably correct as to sign. A 28-hour experiment with a solution 1M HCl and 0.5M  $\text{FeCl}_3$  showed -32 percent effect. Three experiments with a solution 1M HCl, 0.5M  $\text{FeCl}_3$  and 0.5M  $\text{FeCl}_2$ , running for 43, 24, and 39 hours, showed percent effects for  $\text{FeCl}_3$  +26, +7 and -3.6, respectively, with corresponding percent effects for  $\text{FeCl}_2$  -34, -17 and -12. These experiments confirm that ferric chloride can show a negative effect in mixtures and that ferrous chloride does so.

We cannot guarantee that the times were long enough for these mixtures of four components. It may be that more than one steady state of approximately the same stability is possible for such complicated mixtures.

#### DISCUSSION

To account for the fact that in binary gaseous solutions the heavier species is always found to be enriched at the cold (and low) end of the gradient a simple approximate theory has been offered.<sup>2</sup> The theory of Chapman<sup>3</sup> also accounts for this and allows of small modification of result for molecules of widely different diameters.

TABLE II. Transfer of sodium acetate in mixtures with acetic acid in apparatus No. 1A

Moles acetate per liter	1.5	1.5	1.5	1.5	1.2	1.2	0.55
Moles acid per liter	0.17	0.17	1.0	1.0	0.14	0.14	0.063
Hours	20	22	23	24	25	25	<72
Concentration ratio	1.88	2.17	2.05	2.05	2.23	2.15	2.64
Percent effect	54	66	66	66	68	64	90

<sup>†</sup> In the last experiment repairs were needed on the apparatus and 72 hours is the total time, greater than the effective time.

So far, it appears to be a fact that also in binary liquid mixtures the heavier component is enriched at the cold end, even though the heavier component has the smaller molecular weight, as in acetone-water solutions.<sup>4</sup>

<sup>2</sup> L. J. Gillespie, J. Chem. Phys. 7, 530 (1939).

<sup>3</sup> Sydney Chapman, Phil. Trans. (London) A217, 115 (1917).

<sup>4</sup> K. Clausius and G. Dickel, Naturwiss. 27, 148 (1939).

## A Confirmation of the Theory of Thermal Diffusion

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(Received July 8, 1940)

THE experiments reported by Nier<sup>1</sup> and Bardeen<sup>2</sup> demonstrated that the theory of the thermal diffusion column<sup>3</sup> as given by Furry, Jones and Onsager<sup>4</sup> describes reasonably well the separation of the carbon isotopes using methane. Since the construction of a 40-foot column by the authors,<sup>5</sup> further experimental verification of this theory has been obtained.

As described previously, the column was constructed from a 2-inch pipe concentric with a 1-inch standard galvanized pipe from which the galvanizing was removed. (More favorable sizes can be obtained in steel tubes.) The difficulties originally experienced with the heating element were overcome by using four parallel loops of No. 16 Nichrome wire running to the bottom and back through 8-hole porcelain insulators. A one-quarter-inch rod running through a hole in the center of the insulators served as a method of holding them in place and facilitated removing the whole heating element when necessary. The following figures give a description of the column: width of annular space = 0.95 cm; mean circumference of annular space = 13.68 cm; area of annular space = 13.0 sq. cm; volume of annular space 14.2 liters; volume of bulb on the bottom = 1.2 liters; volume of reservoir on top = 24.6 liters; height of heating surface 10.9 meters.

In order to study the performance of the column, methane kindly supplied to us by the Southern California Gas Company, Los Angeles, was admitted at different pressures. Small samples were drawn from the top and bottom of

the column periodically and the ratio of the isotopes determined by analysis on a mass spectrometer. The temperature of the hot surface was maintained at an average value of 316°C, while the cold surface was that of the cold water supply, about 6°C. The average temperature difference was, therefore, 310°C. A current of 27 amperes passing through the heating element at 195 volts gave an average power consumption of about 5.25 kilowatts.

The results of several experiments at 74 cm, 50 cm, 28 cm and 19 cm of mercury are plotted in Fig. 1. The maximum concentration for a given pressure is reached after 125 to 150 hours. A pressure of 28 cm gave larger concentration than either lower or higher pressures. This is to be compared with Nier's<sup>1</sup> results using a column with a spacing of 0.712 cm. The optimum pressure for that spacing was about 45 cm. A further comparison shows that the smaller spacing gives a larger separation for the same length of column. It, therefore, appears that an annular spacing of about 0.5 cm to 0.7 cm is preferable for the type of column described.

Analyses were also made on samples from the top of the column but owing to the difficulty of correcting the mass-spectrographic analyses for the presence of  $\text{C}^{13}\text{H}$  (mass 17 =  $\text{C}^{13}\text{H}_2$ ) they were not considered as reliable as the analyses for samples at the bottom of the column. Correc-

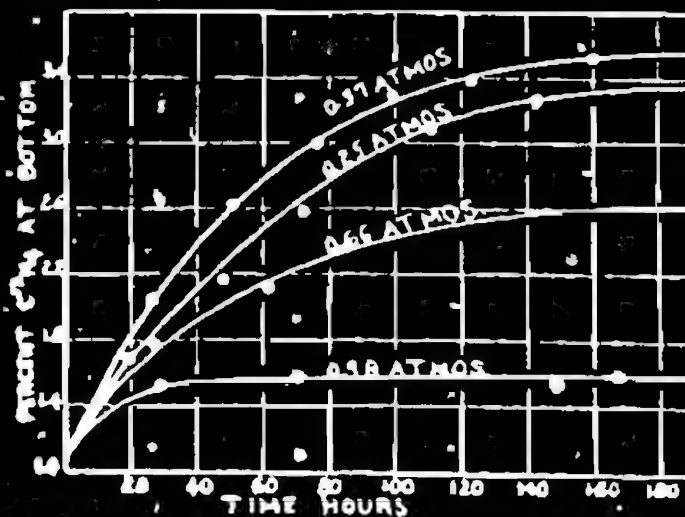


FIG. 1. Variation in the concentration of  $\text{C}_2\text{H}_4$  at the bottom of the column with pressure.

- <sup>1</sup> Nier, *Phys. Rev.* **57**, 30 (1940).
- <sup>2</sup> Bardeen, *Phys. Rev.* **57**, 35 (1940).
- <sup>3</sup> Clausius and Dickel, *Naturwiss.* **26**, 546 (1938); **27**, 148 (1939); Brewer and Bramley, *Phys. Rev.* **55**, 590A (1939); Brewer and Bramley, *J. Chem. Phys.* **7**, 553 (1939); Gröth, *Naturwiss.* **27**, 260 (1939); H. S. Taylor, *Nature* **144**, 8 (1939); T. I. Taylor and Glocker, *J. Chem. Phys.* **7**, 851 (1939); Watson, *Phys. Rev.* **56**, 703 (1939); Gillespie, *J. Chem. Phys.* **7**, 530 (1939); Waldmann, *Naturwiss.* **27**, 230 (1939); Nier, *Phys. Rev.* **56**, 1009 (1939); Onsager and Watcott, *Phys. Rev.* **56**, 474 (1939); Debye, *Ann. d. Physik* **56**, 224 (1939); Waldmann, *Zeits. f. Physik* **114**, 53 (1939).
- <sup>4</sup> Furry, Jones and Onsager, *Phys. Rev.* **55**, 1043 (1939).
- <sup>5</sup> Taylor and Glocker, *J. Chem. Phys.* **7**, 851 (1939).



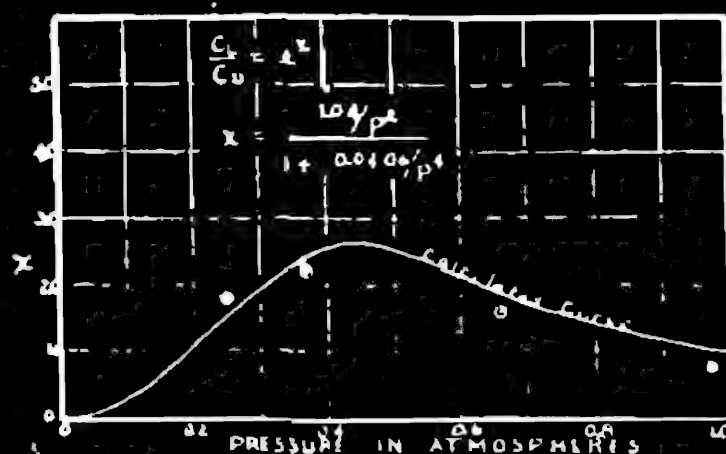


FIG. 2. Variation in the separation factor with pressure.

tions are made empirically by determining the relative heights of the peaks corresponding to masses 16, 17 and 18. The height of the  $\text{C}^{12}\text{H}_4$  peak for water vapor varied from 25 percent to 30 percent of the height of the  $\text{H}_2\text{O}^{16}$ . Subtraction of the calculated height of the  $\text{C}^{12}\text{H}_4$  peak from the total height at mass 17 for the sample gave the height of  $\text{C}^{13}\text{H}_4$  peak. Careful regulation of the energy of the ionizing electron beam in Nier's previous analyses<sup>1</sup> eliminated much of this difficulty. However, weighted mean of the values after equilibrium had been reached gave the following values for the percent of  $\text{C}^{13}\text{H}_4$  at the top of the column: 74 cm = 0.70 percent, 50 cm = 0.53 percent, 28 cm = 0.40 percent, 19 cm = 0.60 percent. The corresponding ratios for the maximum concentration of  $\text{C}^{13}\text{H}_4$  at the bottom divided by the concentrate at the top gives, respectively, 2.13, 4.9, 9.0, and 6.2. There was a very large separation of the impurities. The ratio of the concentration of carbon dioxide at the bottom to that at the top was often more than 1000 to 1.

The variation in the ratio of the concentration of  $\text{C}^{13}\text{H}_4$  at the bottom to that at the top,  $C_L/C_U$ , can be calculated from the theoretical equations of Furry, Jones and Onsager.<sup>4</sup> For any given column, the dependence upon pressure

can be reduced to a simplified equation of the form

$$\frac{C_L}{C_U} = e^{(a/p^2)/(1+b/p^2)} = e^x,$$

where  $a$  and  $b$  are constants and  $p$  is the pressure in atmospheres. Using the dimensions for our column and calculating the constants  $a$  and  $b$  from the theoretical equations in a manner described by Nier<sup>1</sup> and using his value for the coefficient of thermal diffusion, the value of  $x$  is given by

$$x = \frac{1.04 p^2}{1 + 0.0406 p^2}$$

Figure 2 shows a comparison of the theoretical curve with experimental points. The results show reasonable agreement. The theory predicts the observed pressure for maximum separation and the manner in which the separation decreases with increasing pressure. If the observed deviations are real, they seem to indicate that the separation is less at higher pressures than would be predicted by the theory. This may easily result from mass movement of the gas or mixing due to asymmetry and irregularities in the column. This effect may also be more likely in a column with a large spacing (0.95 cm) compared to one with smaller spacing. From a study of the theoretical curves for columns of different annular space separations and from consideration of the transport of heavy carbon, it appears that the spacing in thermal diffusion columns of this type should preferably be between 0.5 cm and 0.7 cm.

We wish to thank Mr. B. M. Lauthere, Technical Supervisor of the Southern California Gas Company, Los Angeles, for the supply of methane gas, and we are indebted to Dr. A. O. Nier for carrying out the mass-spectrographic analyses.



rapidly as the temperature rises, since  $\sigma_{AB} - \sigma_{BA}$  (Fig. 1) decreases very rapidly.

The determination of the energy relations of gaseous films requires apparatus of high sensitivity and considerable accuracy. It is apparent from the equations that as the area of a gaseous film increases the increment of heat content ( $h$ ) approaches zero for spreading, while for expansion it approaches  $h_0$  or about  $116 \text{ erg cm}^{-2}$  at ordinary temperatures, and  $q_0$  approaches  $q_{00}$  or about  $44 \text{ erg cm}^{-2}$ . It is obvious that in this case  $(\Delta H_m)$ , and  $(Q_m)$ , which refer to one mole of the substance of the monolayer, lose their significance, but this is not true of  $h$ , and  $q$ .

It is often forgotten that a film, such as that of an amphipathic (polar-nonpolar) organic substance on water, includes all of the region of the surface which contributes to the surface energy, that is all of the energy associated with the surface which is not accounted for by three-

dimensional thermodynamic treatment which neglects the extent of the surface. The contribution of the first layer of water molecules to this energy is very important, whether it is covered by the organic layer completely or incompletely, and while the second and third, etc., layers rapidly become less important, it is obvious that the first layer of water molecules, though it contributes by far the greatest share of the surface energy due to the water in the surface region, is not the only one involved. Thus in the utilization of the results of this paper in connection with the problem of intermolecular attraction in the monolayer or the film, the energy of spreading and of extension are both of fundamental importance. It has been considered advisable to limit the present paper to the thermodynamics of films. Any applications to molecular theory has been deferred to later papers.

Photo. 24

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## Effect of Gravitational Field on the Thermal Diffusion Separation Method

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A test of the effect of gravitational field on the operation of the Clusius-Dickel thermal diffusion method for gas separation has been made by use of a hollow disk with one hot surface, the whole disk spinning at various speeds. Linear increases in both the equilibrium separations and the rates of separation with increasing centrifugal force were obtained for speeds below a certain maximum value. Above this both the rate and equilibrium separations fell rapidly. He-CO<sub>2</sub> mixtures were used. The results indicate that the standard column would be improved if it were placed in a larger field up to ten times that caused by gravity. Theories for the action of the thermal diffusion column should show this. The apparatus cannot compete with the standard column type for isotopic separations but may have some application to industrial separation problems.

CLUSIUS and Dickel<sup>1</sup> have shown that the counter current flow obtained in the gas between two vertical concentric cylinders, the inner one of which is heated, operates to increase the effect of the thermal diffusion separation of gases.<sup>2-4</sup> The effects of pressure, dimensions of

the apparatus, temperature gradient, and character of the gaseous components all have been investigated in some detail,<sup>5-11</sup> both theoretically

<sup>1</sup> K. Clusius and G. Dickel, *Naturwiss.* 26, 246 (1938).  
<sup>2</sup> S. Chapman, *Proc. Roy. Soc. London A* 90, 1 (1917).  
<sup>3</sup> S. Chapman, *Proc. Roy. Soc. London A* 90, 1 (1917).  
<sup>4</sup> D. Eucken, *Physik. Z.* 32, 288 (1931); *Zeits. f. Physik* 2, 236 (1911).  
<sup>5</sup> T. L. Ebb, *Proc. Roy. Soc. London A* 90, 288 (1921); *ibid.* 90, 670 (1922).

<sup>6</sup> A. K. Brewer and A. Bramley, *Phys. Rev.* 55, 590 (1939).  
<sup>7</sup> K. Clusius and G. Dickel, *Zeits. f. physik. Chemie*, B64, 307 (1939).  
<sup>8</sup> A. O. Nier, *Phys. Rev.* 57, 30 (1940).  
<sup>9</sup> W. Farly, R. Jones and L. Onsager, *Phys. Rev.* 55, 1023 (1939).  
<sup>10</sup> L. Waldmann, *Naturwiss.* 27, 230 (1939); *Zeits. f. Physik* 114, 53 (1939).  
<sup>11</sup> P. Debye, *Ann. d. Physik* 26, 284 (1939).  
<sup>12</sup> J. Bardeen, *Phys. Rev.* 57, 35 (1940).

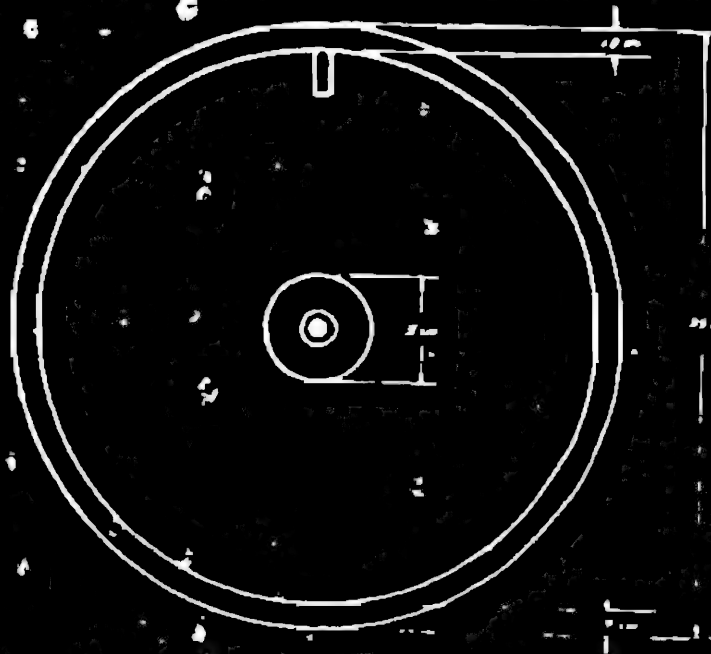


FIG. 1A. Side diagram of the centrifugal thermal diffusion apparatus (drawn to scale).

and experimentally. The authors have attempted to investigate the effects of variation of the gravitational field by use of a rather drastically modified form of the apparatus.

#### APPARATUS

Since the use of centrifugal force is the only way of varying the gravitational field, the apparatus was designed so the necessary counter current would occur perpendicular to an axis of rotation. The standard tube arrangement was replaced by a rotating hollow disk one surface of which was heated and the other cooled. Reservoirs for the gas were provided at the rim and on the axis of rotation as shown in Figs. 1A and 1B. The whole apparatus consisted of brass approximately 1 mm thick. The hot plate was heated by radiation from a Nichrome wire heater wound on a transite sheet and mounted approximately 1 cm from the brass surface while the opposite face was cooled with an air blast from a large electric fan. The rim reservoir was in the shape of a hollow rectangular tire with a volume of 780 cc. A metal cock for sampling the rim gas was located on the inner surface of the rim as shown. A reservoir of 200 cc volume was located on the axis of rotation with a sampling cock attached. The wheel was rotated by a direct-current motor of variable speed by means of a belt running over a wooden pulley mounted around the cylindrical motor on the rotational axis. Three ball

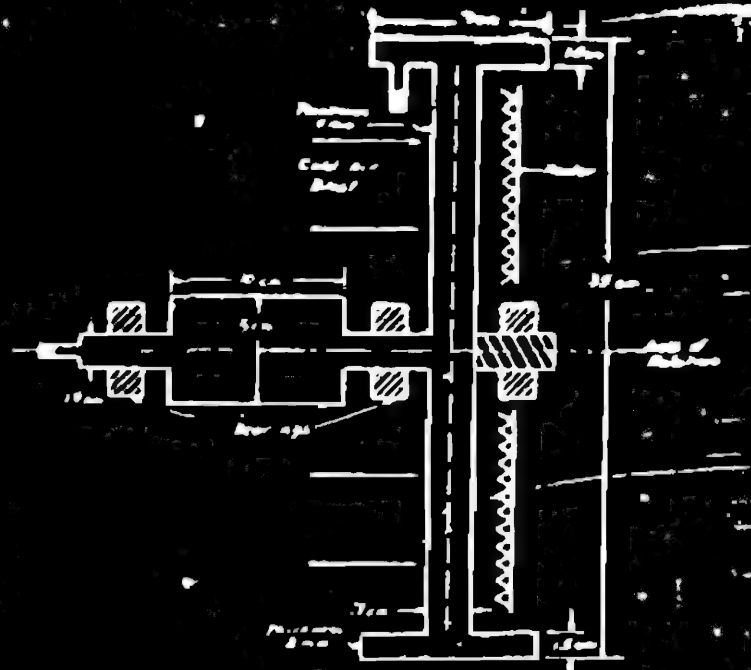


FIG. 1B. Cross-sectional diagram of apparatus (not drawn to scale).

bearings were mounted in iron brackets on a sturdy platform for support of the wheel. The speeds of rotation were measured with a standard stroboscope to about one percent accuracy. The speed of rotation was constant to one or two percent at each speed, though a small amount of irregular vibration set in at the highest speeds of approximately 1000 r.p.m.

The surface temperatures were measured by placing Chromel-Alumel thermocouples in direct contact with the surfaces. Various segments of the heater coil were provided with separate leads so that the area of the heated surface might be varied in both magnitude and distance from the axis of rotation.

The inner surfaces of the plates were 7 mm apart and the volume of the interplate region was 600 cc.

The gas analyses were made on 10-cc samples taken by stopping the wheel and using the rim and axis cocks. It was shown by sampling on the axis during rotation and after stopping that stopping the wheel did not lead to appreciable mixing in the two or three minutes required to take the sample. For most of the work, in which  $\text{CO}_2$  and He were being separated, the analysis was accomplished by freezing out the  $\text{CO}_2$  in a liquid-air trap and reading the pressure change on a capillary manometer. By using capillary tubing throughout the system and taking reasonable care to make the correction accurately for



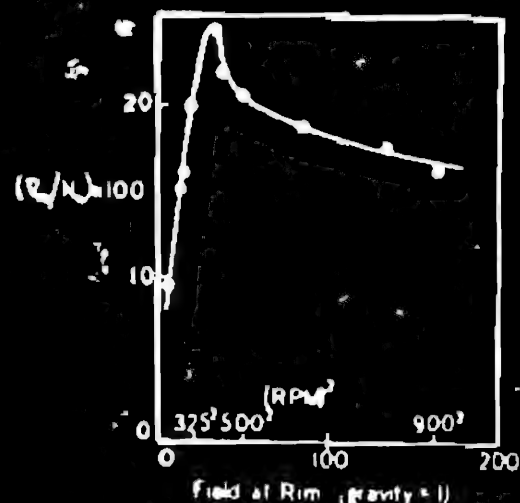


FIG. 5. Equilibrium separation vs. speed of rotation.  $\Delta T = 290^\circ\text{C}$ ,  $N_0 = 0.65$ , heater area =  $278\text{ cm}^2$ . Time for each run, 2 hr.

breaks. Figure 8 gives the dependence of  $\Delta$ , (center) on the heater area, the open circles referring to variations obtained by changing the radius of the inner edge of the heated region, while the solid circles belong to data obtained by varying the radius of the outer edge. Apparently there is no large difference between these two sets of data.

#### DISCUSSION

The gas flow which occurs is a combination of a general movement of the gas near the hot surface inward toward the axis with a transfer flow of part of this hot gas across to the outward moving cold stream as illustrated in Fig. 9. The hot gas flows across to the cold stream at a rate which is constant for each unit of area of plate surface. The truth of this statement is apparent if one notices that both the force acting to push the gas toward the rim and the area across which it moves in flowing toward the rim increase directly with the distance,  $a$ , from the axis of rotation. To maintain approximately constant pressure throughout the gas it is necessary that, instead of compression occurring as the hot gas stream moves inward, a partial movement across to the cold stream must occur to compensate for the decrease in volume available. This also keeps the outward moving stream from suffering a pressure decrease. For a given movement inward from  $a$  to  $a - da$  the decrease in total rate of flow is proportional to  $ada$  because the area across which the flow occurs is proportional to  $a$  and the decrease in the force causing the flow is proportional to  $da$ . This

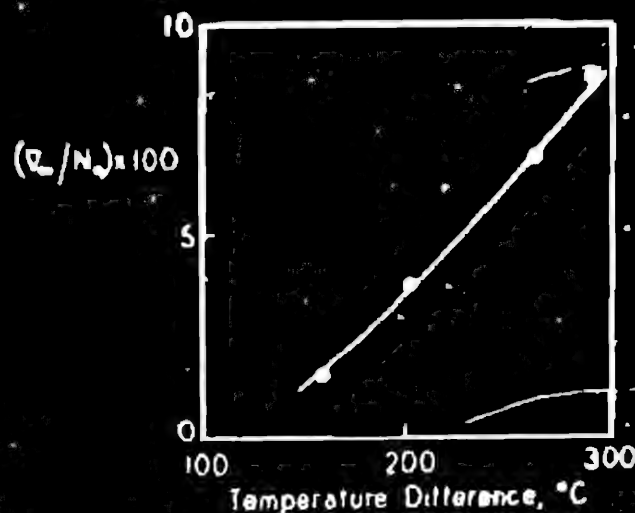


FIG. 6. Equilibrium separation vs. temperature difference.

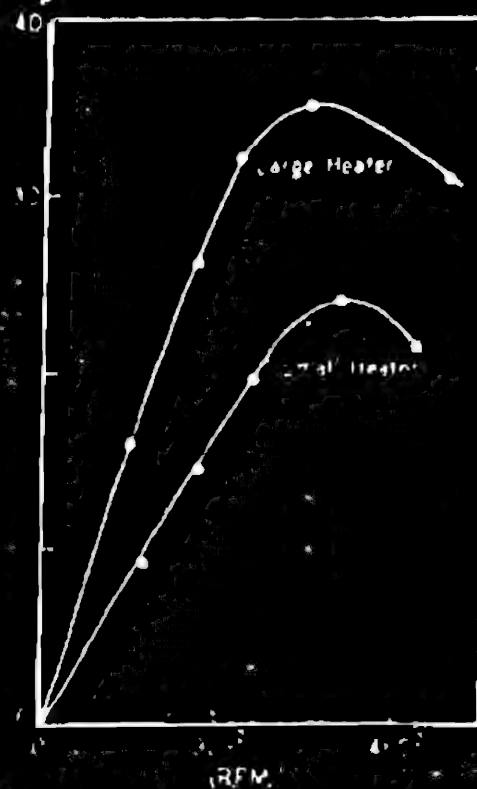


FIG. 7. Effect of heater area on equilibrium separation. For large heater,  $\Delta T = 290^\circ\text{C}$ , heater area =  $445\text{ cm}^2$ ,  $N_0 = 0.62$ . For small heater,  $\Delta T = 290^\circ\text{C}$ , heater area =  $278\text{ cm}^2$ ,  $N_0 = 0.65$ .

decrease must be equal to the flow to the cold stream. The area of the plane parallel to the wheel surfaces across which this flow occurs obviously is proportional to  $ada$  also, so the ratio, the flow from hot to cold stream per unit area of wheel surface, is constant over the whole wheel.

Using the dimensions of the apparatus, the viscosity of the gas, and approximate values for the temperature gradient the velocity of flow is calculated to be about  $150\text{ cm/sec}$ . at the inner edge of the heater and  $500\text{ cm/sec}$ . at the rim at  $375\text{ r.p.m.}$  The hot to cold stream flow is about  $25\text{ cm/sec}$ . under these conditions. At other



speeds the values should be higher or lower in proportion to  $\omega^2$ .

The data show that in the neighborhood of 400 r.p.m. the increases of both the rate and equilibrium separation with increasing  $\omega^2$  break rather sharply into decreases. Both the suddenness of the breaks and the gas velocities at which they occur indicate that turbulence sets in under these conditions.

The Chapman-Enskog thermal diffusion process, which concentrates the light constituent near the hot side, must be established rapidly with respect to the rates of flow below those for 380 r.p.m. or the linear rises shown in Figs. 4 and 5 for  $\lambda$  and  $\Delta_z$  (center) vs.  $\omega^2$  probably would not exist. In order that the counter current action should increase directly with the rate of flow, equilibrium must be nearly completely established for the whole range of speeds. It is conceivable that the breaks in Figs. 4 and 5 are caused by failure to establish equilibrium rather than by turbulence. The chief argument against this interpretation is the sharpness with which the breaks occur.

The linear increase of  $\Delta_z$  and  $\lambda$  with the area of the heated surface indicates strongly that the most important part of the current flow is the transfer of the hot gas to the outward moving cold stream which has been shown above to occur at a constant rate per unit area of heated surface, independently of the distance from the axis of rotation. It seems reasonable that this

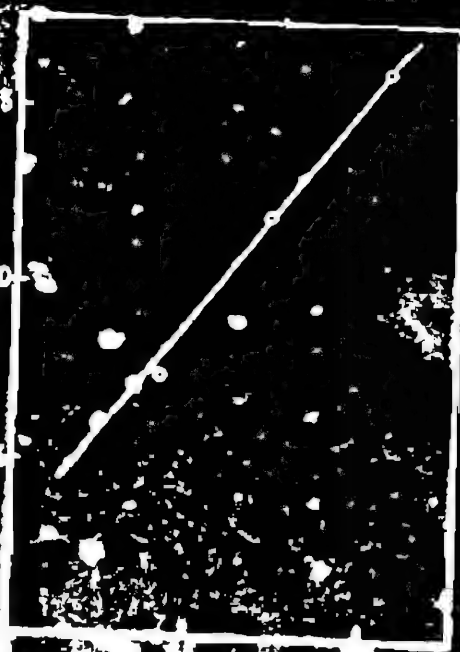


Fig. 8. Equilibrium separation in center zone ( $\omega = 500$  r.p.m.,  $\Delta T = 20^\circ\text{C}$ ).

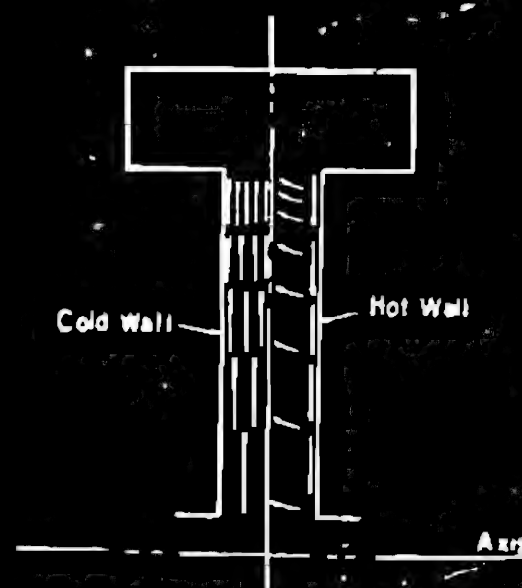


Fig. 9. Type of flow taking place while apparatus is in operation.

should be the case. The gas moving to the cold stream carries an excess of the heavy component with it leaving the inward moving hot stream somewhat purified.

It seems certain also that turbulence should set in for this type of flow at somewhat lower velocities than for those existing in the standard cylindrical thermal diffusion apparatus. On the other hand, it may be true that the condition that equilibrium be established rapidly with respect to the counter current velocity may be less easily violated in the wheel apparatus because of the intimate nature of the contact between the inward moving hot gas and that part of it which is just leaving to join the cold stream. However, since the rises were observed to continue till the main part of the gas was subjected to a field approximately 20 times that due to gravity, it is relatively certain that the ordinary Clusius-Dickel, Brewer-Bramley column would be much improved if it were possible to increase the gravitational field to some ten times the normal value. We should expect all theories for the actions of the columns to show this possibility.

The wheel method seems to offer little promise as a competitor with the columnar type of apparatus. Our apparatus was about equivalent in action to an average column five or six feet long. It is possible, however, that the use of wheels of much larger radii with surfaces heated by flames or superheated steam instead of electricity would afford a less expensive method of separating certain gases of industrial importance.

## A Simple Theory for Separation of Gases by Thermal Diffusion\*

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(Received May 13, 1935)

Equations are derived in a simple manner by equating the net bombardment of each species across a plane between two adjacent thin layers of the gas mixture to the amount of each species returned across the plane by a return flow, which flow is assumed necessary to keep the pressure constant and is assumed to carry back the various species in the proportions in which they exist in the neighborhood. The average temperatures of the layers differ by  $dT$ , but the bombardment of each species is assumed independent and calculable in any layer in the way the pressure of an ideal gas at constant temperature is calculated. The resulting equation for binary mixtures does better than

give the order of magnitude of the observed separations. It appears to give an upper limit, either in agreement with data or somewhat higher, up to about twice the observed value, and to fit data somewhat better than does the approximate equation of Chapman. The agreement is poorest for mixtures containing hydrogen and also when ever the lower temperature is extremely low. The equations for mixtures of any number of species are simple. They indicate that the separation of two heavier species should be improved by addition of a light gas. An attempt to improve the equations by introduction of mean free path is found profitless, unless arbitrary values are to be chosen

## INTRODUCTION

SIXTY years ago Soret discovered that partial separation may occur within a liquid solution if it is placed in a vertical thermal gradient—the hot end being at the upper level in order to avoid convection. A recent investigation is that of Chipman.<sup>1</sup> Thirty-eight years later it was found by Chapman and Dootson<sup>2</sup> that this effect takes place also in the case of mixtures of gases. A recent summary is that of Ibbs.<sup>3</sup> This discovery followed the theoretical prediction of Chapman<sup>4</sup> of the same year. The effect was also predicted by Enskog.<sup>5</sup> Chapman's theory indicates that the molecular diameters are of importance as well as the molecular weights and he has suggested<sup>6</sup> that separation by thermal diffusion may be of value for the separation of gases of equal molecular weight and of isotopes.

Emmett and Shultz<sup>7</sup> found separation by thermal diffusion to be an important source of error in the measurement of chemical equilibrium by the static method in gases at high tempera-

tures, unless special methods are adopted to minimize it.

Separation by thermal diffusion did not promise to be of great practical value until last year Clusius and Dickel<sup>8</sup> found a simple way of cascading the effects. This consists curiously in using a horizontal temperature gradient between two vertical walls. Convection, which can obliterate separation, is here responsible, in properly designed apparatus, for an accumulative effect. Calculation by the aid of the simple equation presented below indicates a multiplication of the effect by a factor of 28 to 50 per meter of length of vertical walls.

Brewer and Bramley<sup>9</sup> have also obtained multiplication of the effect in the same general manner. It is clear that we have a new method of separating gases that promises to work when there is any difference of molecular weight.

The same arrangement has been found to work well in the case of liquid solutions by Korsching and Wirtz<sup>10</sup> and Clusius and Dickel.<sup>11</sup> In this case the molecular weights ordinarily assigned to solute and solvent do not determine the separation, but perhaps rather the partial volumes per gram in the solution; thus, acetone in mixture with water is concentrated at the hot end. In all

\* Contribution No. 424 from the Research Laboratory of Physical Chemistry.

<sup>1</sup> John Chipman, J. Am. Chem. Soc. 48, 2577 (1926).

<sup>2</sup> S. Chapman and F. W. Dootson, Phil. Mag. [6] 13, 248 (1917).

<sup>3</sup> T. L. Ibbs, Physica 4, 1133 (1937).

<sup>4</sup> S. Chapman, Phil. Trans. (London) A217, 115 (1917).

<sup>5</sup> D. Enskog, Inaug. Diss., Uppsala (1917). This is the reference cited by Jeans.

<sup>6</sup> S. Chapman, Phil. Mag. 34, 146 (1917); 38, 182 (1919).

<sup>7</sup> P. H. Emmett and J. F. Shultz, J. Am. Chem. Soc. 54, 3780 (1932); 55, 1376, 1390 (1933).

<sup>8</sup> K. Clusius and G. Dickel, Naturwiss. 26, 546 (1938).

<sup>9</sup> A. K. Brewer and A. Bramley, Phys. Rev. 55, 990 (1939).

<sup>10</sup> H. Korsching and K. Wirtz, Naturwiss. 27, 110 (1939).

<sup>11</sup> K. Clusius and G. Dickel, Naturwiss. 27, 148 (1939).



that follows we are concerned only with gaseous mixtures.

In order to arrive at a working formula, Chapman<sup>12</sup> has simplified his more general theory by assuming rigid, elastic and spherical molecules and by approximation. The resulting approximate formula for a binary mixture is of the form

$$k_t = dx_1/d \ln T = \frac{Ax_1 + Bx_2}{1 + Cx_1/x_2 + Dx_2/x_1} \quad (1)$$

where  $x$  denotes mole fraction,  $\ln$  denotes natural logarithm, and the coefficients  $A$  to  $D$  are functions of the molecular weights and the ratio of the diameters and can be calculated by equations given by him plus the relation  $a_{0-1} = a_{-10}$  which the reader can supply from considerations of symmetry.<sup>†</sup>

The observed separations are usually less and often much less than those calculated from Eq. (1), so that Ibbbs and others deal with a correction factor  $R_t$  equal to the observed value divided by the calculated. Theoretically  $R_t$  is lower, the softer the molecules.

According to Eq. (1) the separation is independent of the pressure. An experimental verification has been given by Ibbbs, Grew and Hirst.<sup>14</sup>

#### DERIVATION OF THE SIMPLE EQUATIONS

Suppose the vertical gas column is composed of thin layers that exchange molecules by independent bombardment. The bombardment per second from a given layer in the upward direction of gas of kind  $i$  is put proportional to the product of its density  $n_i$  in the layer and its mean velocity  $\bar{c}_i$ . The latter is to be calculated from the equation

$$\bar{c}_i = 0.921 C_i = 0.921 (3RT)^{1/2} / m_i \quad (2)$$

where  $C_i$  is the root mean square velocity and  $m_i$  is the square root of the molecular weight.<sup>15</sup> The bombardment per second downward from the next layer, where the density is  $n_i + dn_i$ , and the

<sup>12</sup> See E. Chapman and W. Rowenorth, *Phil. Mag.* [6] 375, 602 (1924).

<sup>†</sup> If this relation were not valid the calculated separation would depend upon the notation (upon which gas subscript 1 denotes).

<sup>14</sup> T. L. Ibbbs, R. E. Grew and A. A. Hirst, *Proc. Phys. Soc. (London)* 43, 456 (1929).

<sup>15</sup> J. H. Jeans, *Dynamical Theory of Gases* (Cambridge University Press, 1925 and 1926). The factor 0.921 disappears through cancellation.

mean velocity is  $\bar{c}_i + d\bar{c}_i$ , corresponding to the temperature  $T + dT$ , is then proportional to the product  $(n_i + dn_i)(\bar{c}_i + d\bar{c}_i)$ . The difference in bombardment (computed as an excess downward) is then proportional to the difference of the products,  $d(n_i \bar{c}_i)$ .

We shall for the simple equations suppose the factor of proportionality the same for all gaseous species, and only later discuss whether this is to be expected.

If now this difference in bombardment is put equal to zero, as the condition for no net flow across the plane separating these two layers, we shall find by applying the ideal gas law that the pressure along the gradient is proportional to the square root of the temperature, a result known to be correct for very low pressures and capillary tubes by the work of Reynolds<sup>16</sup> and of Knudsen.<sup>17</sup> As the gases have been supposed to bombard independently it is evident that there would be no difference of composition along the gradient in the steady state. (There would certainly be transient differences produced if a gradient is suddenly imposed).

At ordinary pressures and tube diameters, however, the pressure is known experimentally to be practically constant throughout the gas in spite of a temperature gradient. We make the following assumption. The gases bombard independently and tend to produce a higher pressure at the higher levels, but a section of gas a few mean-free-paths long cannot sustain a pressure, so that such sections of gas are continually sliding down the tube, and this backward flow carries the various gases in the proportions in which they occur in the section.

In the steady state the difference of bombardment per second is therefore not zero but is equal to  $x_i df$ , where  $x_i$  is the mole fraction of the gas in the mixture at the given level and  $df$  is the total flow per second back down the tube and across the plane. Hence for any gas

$$d(n_i \bar{c}_i) = k x_i df, \quad (3)$$

where  $k$  is the same for all gases at the given level. Therefore at any given level the expression  $d(n_i \bar{c}_i)/x_i$  has the same value for any gas. As the mole fraction equals the density of the species

<sup>16</sup> Osborne Reynolds, *Phil. Trans.* 170, 11, 727 (1870).

<sup>17</sup> M. Knudsen, *Ann. d. Physik* 23, 797 (1927).



divided by the sum of all the densities at the same level the expression  $d(n_i/n)/n_i$  is the same for any gas, and hence also  $(d \ln n_i + d \ln c_i)$ .

Now by Eq. (2),  $d \ln c_i = \frac{1}{2} d \ln T$  and from the law of ideal gases, applied to mixtures, we have  $p x_i = n_i R T$  and therefore for constant pressure along the gradient  $d \ln n_i = d \ln x_i - \frac{1}{2} d \ln T$ . Making use of these two differential equations and of the substitution of  $1/m_i$  for  $c_i$ , we find that  $1/m_i (d \ln x_i - \frac{1}{2} d \ln T)$  is the same for each gas, or

$$= 1/m_1 (d \ln x_1 - \frac{1}{2} d \ln T) \\ = 1/m_2 (d \ln x_2 - \frac{1}{2} d \ln T) \\ \Rightarrow m_1 (d \ln x_1 - \frac{1}{2} d \ln T) = m_2 (d \ln x_2 - \frac{1}{2} d \ln T), \quad (4)$$

where  $i$  is any species.

When there are only two species,  $dx_2 = -dx_1$  and we easily find that

$$\frac{d \ln x_1}{d \ln T} = \frac{x_2(m_2 - m_1)}{2(m_1 x_1 + m_2 x_2)} \quad (5)$$

For better comparison with Chapman's Eq. (1) it can be put in the form

$$k_1 = \frac{dx_1}{d \ln T} = \frac{B' x_2}{1 + D' x_2 x_1} \quad (6)$$

where  $B' = \frac{1}{2}(m_2 - m_1)$  for natural logarithms and  $D' = m_2/m_1$ . In view of the crude treatment of the thermal gradient used above, the similarity of the two equations, especially with respect to the occurrence of the temperature, is surprising. No assumption about the diameters (such as that their ratio is zero or unity) has been found that will make Eq. (1) agree with Eq. (5).

Chapman's equation has been used with approximate integration, by assuming the mole fractions on the right-hand side as constant and equal to their average values. The same should equally suffice for Eq. (5). However, the integrated result for it is

$$m_2 \log \frac{x_1'}{x_1} - m_1 \log \frac{(1-x_1')}{(1-x_1)} \\ = \frac{1}{2}(m_2 - m_1) \log (T'/T), \quad (7)$$

where the primes indicate corresponding limits. This can be solved by successive approximations, or better, if the whole separation curve is

desired for a given ratio  $T'/T$ —one may calculate by it the ratio  $b = x_1'/x_1$  from assumed values of the ratio  $a = (1-x_1)/(1-x_1')$ , then find  $x_1' = b(a-1)/(b-1)$ . The ratio  $a$  runs between the limit 1 (at  $x_1 = 1$ ) and the limit (at  $x_1 = 0$ ) whose logarithm equals  $\frac{1}{2}(m_2/m_1 - 1) \log (T'/T)$ .

If the pressure is not assumed constant, Eqs. (4) and (5) are readily modified and the integration easily carried out for two species if we know how the logarithm of the pressure varies with  $\log T$  in simple series expansion.

According to Eq. (5) the maximum value of  $k_1$  for two given temperatures is reached when

$$x_1 = [1 - (m_1/m_2)^{1/2}] / (1 - m_1/m_2), \quad (8)$$

where, it will be remembered, the  $m$ 's denote square roots of molecular weights. The maximum is at  $x_1 = 0.5$  when  $m_1/m_2 = 1$ , and at  $x_1 = 1$  when  $m_1/m_2 = 0$ . Experimentally the maximum is found at  $x_1$  somewhat exceeding 0.5 for  $m_1/m_2$  less than unity, except perhaps in mixtures of hydrogen and helium. Here Elliott and Masson<sup>17</sup> believed the maximum to lie on the other side of the curve, but the four points are somewhat irregular and may not quite determine the maximum.

When there is any number  $q$  of species we have, comparing gas 1 with any gas  $i$  with the aid of Eq. (4)

$$\frac{d \ln x_1}{m_1} = \frac{dx_1}{m_1 x_1} + \frac{1}{2} \left( \frac{1}{m_1} - \frac{1}{m_i} \right) d \ln T, \quad (9)$$

$$\frac{m_i x_i}{m_1} d \ln x_1 = dx_1 + \frac{1}{2} \left( \frac{m_i x_i}{m_1} - x_i \right) d \ln T. \quad (10)$$

If we add up the  $q$  Eqs. (10) in which  $i$  runs over all values from 1 to  $q$ , noting that  $\sum dx_i = 0$  and  $\sum x_i = 1$ , we shall eliminate all variations of mole fraction except  $dx_1$  and obtain, after multiplying both sides by  $m_1$ ,

$$\sum m_i x_i d \ln x_1 = \frac{1}{2} (\sum m_i x_i - m_1) d \ln T. \quad (11)$$

$$\text{Hence } d \ln x_1 / d \ln T = \frac{1}{2} (1 - m_1 / \sum m_i x_i), \quad (12)$$

where the summation is over all species.

If (at very low pressures and with tube of small diameter) the pressure is not constant over the gradient one can show that the right-hand side of Eq. (12) must be multiplied by

<sup>17</sup> G. A. Elliott and Irvine Masson, Proc. Roy. Soc. (London) A108, 378 (1925).

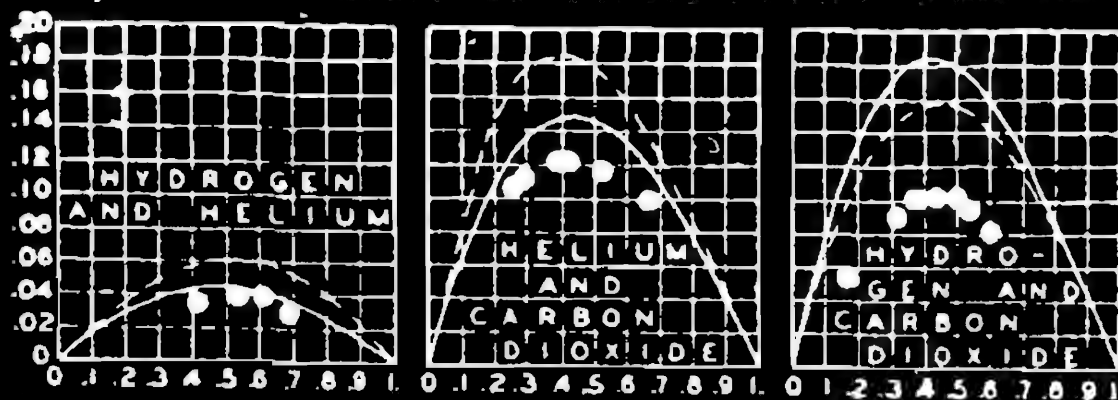


Fig. 1. Excess mole fraction of the heavier gas in the cold chamber plotted against the mole fraction of the heavier gas in the cold chamber. Data of Elliott and Masson. Temperatures about 0° and 500°. Solid curves from Eq. (7), broken curves from Eq. (1).

( $1 - 2d \ln p / d \ln T$ ). In the limit, when the bombardment is not accompanied by a return flow,  $p = k \sqrt{T}$ , the factor becomes zero, and thermal separation vanishes.

Equation (12) can be applied to find the theoretical effect of foreign gases on the separation of two gases of kinds 1 and 2. No experiments seem to have been made of this kind.

We have for gas 2

$$d \ln x_2 / d \ln T = \frac{1}{2} (1 - m_2 \sum m_i x_i) \quad (13)$$

from which together with Eq. (12)

$$\frac{d \ln (x_1/x_2)}{d \ln T} = \frac{m_2 - m_1}{2 \sum m_i x_i} \quad (14)$$

According to this equation, the relative separation of two gases by thermal diffusion, defined as the left-hand side of Eq. (14), is inversely proportional to the mean root-molecular weight of the mixture and it can therefore be increased by addition of a third gas of low molecular weight to decrease this mean. The limit of the mean for addition of gas 3 is  $m_3$ , approached as the composition approaches that of pure gas 3, and at the limit the effect of adding gas 3 would be to multiply the relative separation by the ratio  $(m_1 x_1 + m_2 x_2) / m_3$ , where  $x_1$  and  $x_2$  are the mole fractions before addition of the third gas. For the separation of the chlorine isotopes 35 and 37 by thermal diffusion of hydrogen chloride the separation would be multiplied in the limit a little better than four times by the use of hydrogen as third gas. This consequence of Eq. (14) has recently been pointed out by the author.<sup>10</sup>

<sup>10</sup> L. J. Gilkrie, *J. Chem. Phys.* **7**, 438(L) (1939).

#### COMPARISON WITH EXPERIMENTAL RESULTS

Figure 1 shows the separations found by Elliott and Masson<sup>17</sup> for three mixtures of gases over practically the same temperature intervals, about 0° to 500°. The separations in percent are plotted against the percent of heavy gas in the cold end, though average percent of heavy gas is more convenient for theoretical purposes. The continuous line is that given by the integrated Eq. (7) and the broken line is that given by Chapman's approximate Eq. (1) with approximate integration.

The agreement of Eq. (7) in the first two cases ( $H_2$  and He, He and  $CO_2$ ) is impressive, but the disagreement in the third case ( $H_2$  and  $CO_2$ ) is not to be denied, as the indications are that the data are not too low, but rather somewhat too high.

When other data are taken into account it is found that the observed separations are usually less than those calculated from Eq. (5) or (7), so that Eq. (5) is good enough with approximate integration and comparisons are best made with the aid of the fraction which the observed effect is of the calculated. When Eq. (1) is used this fraction is denoted by  $R$ . When Eq. (5) or (7) is used this will be denoted by  $C$ .

Now either Eq. (1) or (5) ought to be valid for the purpose of comparing one investigator's work with that of another when the temperatures and compositions are not too different. Yet the work of different investigators does not agree very well when compared in this way, as can sometimes be seen with little or no calculation. Furthermore Ibbs and Wakeman<sup>18</sup> have pointed

<sup>18</sup> T. L. Ibbs and A. C. R. Wakeman, *Proc. Roy. Soc. (London)* **A134**, 613 (1932).



TABLE I. Values of  $100C$  over a range of temperature.

Lower temperature	-41	-51	-58	-78	-119	-179
$100C$	84	87	85	75	61	47

TABLE II.  $100C$  for various mixtures.  $C$  equals ratio of observed separation over that calculated by Eq. (5).

	He	Ne	A	H <sub>2</sub>	N <sub>2</sub>	CO <sub>2</sub>	MEAN
He	95	78	87	83	86		
Ne	95	100	74	81	90		
A	78	100	44	54	76		
H <sub>2</sub>	87	74	44	54	62		
N <sub>2</sub>			81	54	88		
CO <sub>2</sub>	83			60	88		
H <sub>2</sub> O				52			

out that  $k_i (= dx/d \ln T)$  is not really determined by the composition as both equations indicate. Thus for 31 percent CO<sub>2</sub> with H<sub>2</sub> they find  $R_i = 0.42$  for temperatures below 144° and 0.60 between 143 and 300°. Also at very low temperatures  $k_i$  and therefore  $C$  decrease very considerably. Thus for the experiment of Hils, Crew and Hirst<sup>10</sup> with 46 percent N<sub>2</sub> and argon, higher temperature = 16°, the values of  $C$  are as given in Table I. The upper limit is 85. Similar results hold for other mixtures investigated by them including mixtures of monatomic gases.

A table of  $C$  values cannot therefore be very exact. In the Table II the results for extremely low temperatures have been omitted (or the upper limit found) and other results averaged. It is not presented as a critical summary of data, but only to illustrate the general degree of applicability of Eq. (5).

The values of  $100C$  range from 100 down to 44, the mean for hydrogen being especially low. In certain cases  $R_i$  (the corresponding ratio for the Chapman approximate equation) has been calculated and Table III gives a comparison for nine cases. When  $C$  is not the same in Tables II and III it is because in Table III the value is for the same experiment for which  $R_i$  had been calculated, whereas for Table II some attempt at averaging was made.

TABLE III. Comparison of  $C$  and  $R_i$ .

Class	He, Ne	He, A	He, H <sub>2</sub>	He, CO <sub>2</sub>	Ne, A	Ne, H <sub>2</sub>	H <sub>2</sub> , CO <sub>2</sub>	H <sub>2</sub> , N <sub>2</sub>	Ne, CO <sub>2</sub>	MEAN
$100C$	65	86	87	83	100	74	50	62	88	80.3
$100R_i$	73	76	72	78	53	74	54	63	44	65.4

The mean difference is favor of  $C$  is 15. The highest figure for  $R_i$  is 78, whereas  $C$  exceeds this in six cases. It seems clear that Eq. (5) is not only simpler to apply than Eq. (1) but gives considerably better results. Furthermore the results of Eq. (5) are sometimes excellent.

### GENERAL DISCUSSION

One may expect that the observed separations will not exceed those calculated by the new Eq. (5) and will seldom (except at extremely low temperatures) fall below 50 percent of the calculated values.

It may be, however, that the proviso should be made that the experimental value be obtained by apparatus not too different in character from the various arrangements already used. For, the equations purport to determine the separation by means of only thermodynamic variables. Now the problem does not look like a thermodynamic one, and nonthermodynamic variables should be expected to enter. But, perhaps because they do not enter the approximate equation of Chapman, the experimenters often report only thermodynamic variables, omitting any detailed description of apparatus dimensions, and they do not appear to have studied the possible effect of any variables other than the pressure, composition and the two extreme temperatures. There is, however, enough agreement between different experiments with different apparatus to indicate that thermodynamic variables are at least sufficient to nearly determine the degree of separation in ordinary practice.

### SEPARATION BY VERTICAL PARALLEL WALLS AT DIFFERENT TEMPERATURES

If the quantity  $C$  is calculated for the experiments of Clusius and Dickel,<sup>8</sup> values are found of a different order of magnitude. Thus for their separation of the isotopes of chlorine  $100C$  is found to be 5000. This indicates that their apparatus is acting as an ensemble of 50 units in



cascade. As the total length was 290 cm, the height of each equivalent unit was 5.8 cm.

For the separation of oxygen from air they used apparatus of two lengths: 1 meter and 2.9 m. The heights of the equivalent units as calculated from Eq. (7), the nitrogen being treated as pure, are 3.55 and 3.58 cm.

In the case of their separation of carbon dioxide and hydrogen they reported 40 percent  $\text{CO}_2$  at the hot end and 100 percent at the cold end of a 1-meter tube. Using the integrated Eq. (7) with a value of  $C = 0.60$  it is found that even 27 units in cascade would produce 99.94 percent  $\text{CO}_2$  at the cold end.

#### IMPROVEMENT OF THE SIMPLE EQUATIONS

If the layers of gas in the vertical thermal gradient were strictly isothermal, differing progressively by  $dT$  in temperature, the resulting equations ought to be about as accurate as the calculation of a partial pressure by similar methods, i.e., within one percent even for mixtures containing carbon dioxide, except when one temperature is extremely low.

There is no mathematical difficulty here. The same equations also result if we call the temperature  $T - dT$ ,  $T$ , and  $T + dT$  at three successive planes serving to bound two layers and write  $T - dT/2$ ,  $T$ , and  $T + dT/2$ , etc., for the average values in the lower layer and expressions like  $T + dT/2$  for the average in the upper layer. But there is a physical difficulty. For it does not seem probable that the different species come across the plane of reference from the same average distance. Let the species  $i$  come from below from the average distance  $L_i$  where the temperature is  $T - L_i/L dT$ , the density  $\rho_i = L_i/L d\rho$ , etc., and come from above from the average distance  $L_i$  (or  $L_i$  plus a differential—it does not matter) where the temperature is  $T + L_i/L dT$ , etc. Over the small interval the functions can be supposed linear; the quantity  $L$  is a grand average distance over all species.

By this procedure all the preceding equations are obtained again with the sole difference that every root molecular weight  $m_i$  is now divided by  $L_i$ .

As the equations are homogeneous in  $m_i$ , the  $L_i$ 's cancel if assumed equal. It appears that the best we can do at present is to put the quantities  $L_i$  equal (or ignore them). If we put them equal to the mean free paths, as calculated for mixtures from any ordinary values of molecular diameters, the calculated separations diverge for the most part worse from the data. This can be seen from the equation for binary mixtures in the form

$$\frac{d \ln x_1}{d \ln T} = \frac{x_2 (m_2/m_1)(L_1/L_2) - 1}{2 x_1 + (m_2/m_1)(L_1/L_2)x_2} \quad (15)$$

Now the right-hand side already comes out too great when  $L_1/L_2 = 1$ , particularly when  $m_2/m_1$  is large, as in the case of carbon dioxide (2) and hydrogen (1). But as the ordinary free path of hydrogen in a 50 percent mixture is about three times that of carbon dioxide, this is equivalent to taking in the simple equation a threefold greater ratio of  $m_2/m_1$ , which results in a larger calculated separation. Except in the case of helium,  $L_1/L_2$  usually exceeds 1 as estimated in this way when  $m_2/m_1$  is taken to exceed unity.

But in dealing with gas mixtures, particularly when the identity of the molecule crossing a plane is so important, the mean free path that must be used for  $L_i$  must take account of the "persistence of velocity." In the case of carbon dioxide and hydrogen, the average distance that a molecule of carbon dioxide goes before being much influenced in its progress by collision may well exceed the corresponding distance for a hydrogen molecule. According to the present body of data it appears impossible to obtain an agreement by means even of an arbitrary (but "smooth") persistence function of the ratios of the molecular weights. We may suppose that the persistence is determined in part by the nature of the intermolecular forces, in which case the ordinary mean free path is useless and the simple equations obtained above are probably the best working equations that can be obtained at present.

It is of interest that Chapman's approximate Eq. (1) for these two gases can only fit data if the diameter of carbon dioxide is assumed smaller than that of hydrogen (about one-third).

TABLE III. Densities of some solutions  $M$  = moles per liter of solution.

SOLUTION	DENSITY AT 25°
0.5 $M$ in HCl and 1 $M$ in $FeCl_3$	1.0312
1 $M$ in $FeCl_3$	1.0210
0.5 $M$ in HCl (made up at 25°)	1.0060
0.5 $M$ in HCl (made up at 18°)	1.0076

In the statement of this fact we may understand the heavier component of a binary mixture to be that one which has the greater density when pure, or, and perhaps somewhat better, we may define the heavier component to be that one which increased the density of the solution when it is added at constant temperature and pressure; i.e., that one of a binary mixture for which the function

$$f_i = m_i (\partial \rho / \partial m_i)_{T, p, m_j} = a_i (1 - a_i) (\partial \rho / \partial a_i)_{T, p, a_j} \quad (1)$$

is positive, where  $\rho$  is the density of the solution,  $m_i$  is the mass of the substance  $i$  and  $a_i$  is the mass of the substance  $i$  divided by the total mass.

The function is of course positive for that component of a binary ideal gas mixture which has the greater molecular weight.

The same definition recommends itself for the

consideration of solutions containing more than two components. For any solution the sum of the functions for all the components is zero by Euler's theorem for homogeneous functions of the zero order, and hence at least one component must be heavy, and at least one must be light (except for the trivial case at a point where the density at constant  $T$  and  $p$  is a maximum or a minimum).

The rule holds for all the experiments that have come to our attention, including our own on binary mixtures, that the cold-end enrichment in a binary liquid or gaseous solution has the same sign as the function  $f_i$ .

But from the results here reported for the chlorides of iron in HCl solution it appears that this rule does not always apply to ternary mixtures.

In the case of ferric chloride some density data of Kanitz<sup>4</sup> together with the data for HCl from the *International Critical Tables* indicate that the function  $f_i$  for ferric chloride is positive as usual (though the cold-end enrichment was found to be negative). His densities are relative to water at 25° and have been computed relatively to water at 4° for Table III.

<sup>4</sup> A. Kanitz, *Zeits. f. physik. Chemie* 22, 336 (1897).



# The Production of Concentrated Carbon (13) by Thermal Diffusion

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A thermal diffusion column 74 feet long and employing methane is being used for the concentration of  $C^{13}$ . Every 48 hours 308 milligrams of methane are removed in which the  $C^{13}/C^{12}$  ratio has been increased 11.5 times. The power consumption is 6490 watts and six liters minute of cooling water is used. An expenditure of 156 kw hr. of energy thus results in a transport of 13.5 mg. of  $C^{13}$  per 24 hours. The measured output is in good agreement with the value computed from the theory.

THE thermal diffusion method of Clusius and Dickel<sup>1</sup> has been used in a number of cases<sup>2,3</sup> to produce methane in which the  $C^{13}$  content was increased. Two years ago a 24 foot column was constructed in this laboratory with which it was possible to obtain a satisfactory check<sup>4</sup> of the theory of operation proposed by Furry, Jones and Onsager.<sup>5</sup>

The question arose as to how this column might be extended to become useful for the production of methane in which the  $C^{13}$  content had been increased from a normal 1.1 percent to at least 10 times this value. The fact that brass tubing is made in lengths of approximately 12 feet and that there was available a vertical space of approximately 36 feet suggested the use of a 72-foot column broken into two parts.

Furry, Jones and Onsager<sup>5</sup> have shown that if  $\tau$  represents the transport of gas along the tube and if  $C_1$  is the concentration of  $C^{13}H_4$  at any point along the tube and if the rate of removal of  $C^{13}H_4$  from the lower end of the column is  $C_1\tau$ , one may write

$$C_1\tau = H \left[ C_1(1 - C_1) - \frac{1}{2A} \frac{dC_1}{dz} \right] + C_1\tau, \quad (1)$$

where  $A$  and  $H$  can be computed in terms of various constants for the gas, and the pressure, temperature and dimensions of the column.

The solution of (1) subject to the condition

<sup>1</sup> K. Clusius and G. Dickel, *Nature* **26**, 546 (1938); **27**, 148 (1939).

<sup>2</sup> H. S. Taylor, *Nature* **144**, 8 (1939); T. I. Taylor and G. Glockler, *J. Chem. Phys.* **7**, 851 (1939); **8**, 843 (1940); W. W. Watson, *Phys. Rev.* **56**, 703 (1939); **57**, 899 (1940).

<sup>3</sup> A. O. Nier, *Phys. Rev.* **57**, 30 (1940).

<sup>4</sup> J. Bardeen, *Phys. Rev.* **57**, 35 (1940).

<sup>5</sup> W. H. Furry, R. C. Jones and L. Onsager, *Phys. Rev.* **55**, 1083 (1939).

that  $C_1$  is small is

$$C_1\tau = C_1^0 (1 + n) [1 + \exp \{- (1 + n) 2AL\}], \quad (2)$$

where  $n = H$  and  $L$  is the length of the column.

Table I gives the computed concentration and transport under various operating conditions for a 72 foot column similar to the 24 foot one previously investigated.

In substituting in Eq. (2)  $2AL$  was taken as

$$(0.58 - p) (1.63 + 0.208 p), \quad (3)$$

where  $p$  is in atmospheres pressure. This value is three times the empirically measured value<sup>1</sup> for the 24 foot section.  $H$  was computed from Eq. (30) of reference 5.

The concentrations given are all somewhat high as they are based upon the assumption that  $C_1 < C_1^0 = C_1^0$ . Only in the cases of the high concentrations would this discrepancy be serious. It appears that operation at a pressure of one atmosphere with a drain of 0.150 g. of  $C^{13}H_4$  per 24 hours would give sufficient concentration with reasonable economy. Moreover operation at a pressure of one atmosphere or slightly over would minimize difficulties should the system have any small leaks.

TABLE I. Approximate separation factor  $C_1/C_1^0$  for  $C^{13}$  and transport in mg. of  $C^{13}$  per day for average  $C_1^0 = 0.01$ .

Press. (atmos.)	0.6	0.8	1.0	1.2
$C_1/C_1^0$	1.4	1.6	1.8	2.0
Trans- port	16.9	28.1	42.1	58.0
$C_1/C_1^0$	9.1	16.3	22.1	28.0
Trans- port	9.1	16.3	22.1	28.0
$C_1/C_1^0$	6.5	10.3	13.2	16.0
Trans- port	6.5	10.3	13.2	16.0
$C_1/C_1^0$	3.76	5.82	7.2	8.8
Trans- port	3.76	5.82	7.2	8.8
$C_1/C_1^0$	2.85	4.22	5.10	6.11
Trans- port	2.85	4.22	5.10	6.11



We compared the absorption of the hard  $\gamma$ -rays with that of annihilation radiation from the 3.5-hr.  $\text{Cu}^{64}$ , under enough lead to reduce the ionization to less than eight percent. The Cd  $\gamma$ -ray is more penetrating. An experiment with coincidence counters also showed it to be for the most part a nuclear  $\gamma$ -ray. We found evidence for the expected Auger electrons from a sample of pure radioactive Cd, distilled in vacuum, from bombarded silver. This distillation technique should find many uses in the field of artificial radioactivity.

From the ratio of the numbers of K and L conversions, a theory proposed by one of us<sup>1</sup> requires a multipole order of  $4 \pm 0.1$  for the transition between the two silver states. The measured internal conversion coefficient of 98 percent demands a similar, but not quite so precise value of this multipole order, from the theory of Dancoff and Morrison.<sup>2</sup> If we assume the value 4 to be correct, and calculate the lifetime of a 93.5 keV level in Ag by means of Weisskopf's formula<sup>3</sup> corrected by Hebb and Uhlenbeck<sup>4</sup> to include decay by internal conversion, we obtain an expected value of 30 sec. On this theory, multipole orders of 3 and 5 would give lifetimes of about  $10^3$  and  $10^4$  sec., respectively. The agreement between these three methods of computing the order indicates further that the transition is an electric rather than a magnetic  $2^1$  pole, so that the spin difference between the two states in silver is 4 units. In view of the approximations made in the theory, the agreement with respect to lifetime is a most encouraging check.

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- <sup>1</sup> L. A. Delmas, A. N. Ridenour, R. Sherr and M. G. White, *Phys. Rev.* **55**, 113 (1939).  
<sup>2</sup> G. E. Valley and R. L. McCrory, *Phys. Rev.* **55**, 322 (1939).  
<sup>3</sup> T. Dancoff and C. H. Westcott, *Nature* **134**, 177 (1934).  
<sup>4</sup> G. Gethen, *Nature* **135**, 1095 (1935).  
<sup>5</sup> E. Nelson, *Phys. Rev.* **57**, 252 (1940). E. Nelson and M. H. Hebb, *Phys. Rev.* **58**, 100 (1940).  
<sup>6</sup> S. M. Dancoff and P. Morrison, *Phys. Rev.* **55**, 122 (1939).  
<sup>7</sup> M. H. Hebb and G. E. Uhlenbeck, *Physica* **5**, 605 (1938).

#### Elementary Derivation of Thermal Diffusion

Thermal diffusion is usually thought not amenable to elementary derivation.<sup>1</sup> It may, then, be of value to point out a method of showing its existence and sign from elementary considerations. Thermal diffusion shows itself if a mixture of two gases is kept at a non-uniform temperature. It causes a gradient of the partial pressure of either gas which is observed as a partial separation of the gases. To support this partial pressure gradient the "partial gas" must experience a constant force due to collisions with molecules of the other gas. Hence there must be a continual net transfer of momentum from one gas to the other. To evaluate this one can find the momentum change suffered by a molecule of type "1" in a collision with a "2" molecule and sum over all collisions.

The result of this may be most easily understood by the following very rough treatment. Consider the heavier

molecules as stationary, the light gas as composed of two streams of uniform velocities moving toward the cold and hot sides, respectively. The velocity of the stream coming from the hot side is somewhat greater than the velocity of the other stream. Each light molecule with velocity  $V$  loses its momentum to the heavy molecules at a rate  $V\sigma$  where  $\sigma$  is the cross section for complete dissipation of momentum. Since each stream must carry the same momentum per cm<sup>2</sup> (to make the net particle flux zero) the momentum transfer per second of the streams is proportional to  $V\sigma$ . The dependence of  $V\sigma$  on the velocity can be found by a dimensional argument. Let the molecules interact by an inverse  $s$ th power repulsion,  $F = -K/r^s$ . Then  $\sigma$  may depend on  $K$ , on the mass of the light molecule (strictly the reduced mass), on  $V$ , and on  $s$ . From the dimensions of these quantities it is seen that  $\sigma$  must be proportional to  $(K/mV)^{1/(s-1)}$  or to  $V^{-1/(s-1)}$ . Thus  $V\sigma$  varies as  $V^{(s-1)/(s-1)}$ . This gives a force supporting an excess of light component at the hot side for molecules "harder" than Maxwellian molecules ( $s=5$ ) or at the cold side for  $s \leq 5$  and no thermal diffusion for Maxwellian molecules.

A more rigorous treatment would take account of the motion of the heavy molecules and of the distribution in velocities of both types. Denote by  $f_1(c_1)$  and  $f_2(c_2)$  the velocity distributions of the light and heavy gases, respectively, normalized to their respective particle densities. Define a cross section for momentum transfer as follows: If a uniform stream of particles of mass  $\mu$ , the reduced mass of the collisions, impinges on a scattering center  $F = -K/r^s$ , then the total momentum transferred to the scattering center is the product of the cross section,  $\sigma$ , and the momentum per cm<sup>2</sup> of the stream. Then as before this cross section must vary with the relative velocity as  $V^{-1/(s-1)}$ . The momentum gained per second by the light gas is then given by the expression

$$\int \int \frac{1}{2} (p_1 - p_2) f_1(c_1) f_2(c_2) \sigma V dc_1 dc_2 \\ = C \int \int (p_1 - p_2) f_1(c_1) f_2(c_2) V^{(s-1)/(s-1)} dc_1 dc_2$$

where  $p_1$  and  $p_2$  are the momenta of the light and heavy molecules, respectively.  $C$  is positive and does not depend on the velocities,  $f_1(c_1)$  and  $f_2(c_2)$  while not Maxwellian still must obey the relationship  $\int f(c) p dc = 0$  since this expression divided by  $m$  is the rate of flux of molecules. Hence for  $s=5$  the term in  $V$  drops out and the integral vanishes. For harder molecules the collisions of high relative velocity are more effective. The collisions of highest relative velocity are predominantly those in which the lighter molecule is coming from the hotter region and the heavier from the colder region. Thus the resulting force is such as to support a greater partial pressure of light molecules in the hot part of the gas, and conversely as before for molecules softer than  $s=5$ . It may also be seen from this argument that the effect must be proportional to the product of the two fractional concentrations and to the relative mass difference.

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- <sup>1</sup> S. Chapman, *Phil. Mag.* **7**, 1 (1910). Furry, Jones, and Unger, *Phys. Rev.* **54**, 1041 (1939).



From the standpoint of maximum power economy it would be desirable to use a column for which the average circumference of the annular gas-containing space varied approximately inversely with the concentration along the column.<sup>14</sup> Such a column would not be practical to build so one would reduce the size by a number of stages having progressively smaller cross sections from top to bottom. Such an arrangement would not give quite the output of a continuous large column but would require considerably less power.

The arrangement used in the present work is shown in Fig. 1. Table II gives the dimensions and other pertinent data concerning the several sections. Section 1 is the original one<sup>14</sup> and section 2 was an expansion added later. The combination operated at a pressure of 0.8 atmosphere with the hot walls at 300°C and produced 170 milligrams of  $C^{14}$  per 24 hours in which the  $C^{14}$  content had been increased by a factor of 6.0. In the fall of 1940 section 3 was added, the temperatures of the hot walls raised to approximately 380°C and the pressure to 1 atmosphere.

Section 1 is connected to the 150-liter reservoir by means of two leads of ordinary  $\frac{1}{4}$ -inch copper refrigerator tubing. A pump  $P_1$  circulates the gas. This consists merely of an iron cylinder which moves up and down with a period of approximately one second in a brass tube surrounded by solenoid actuated by a multivibrator oscillator. A small piece of rubber dam over a

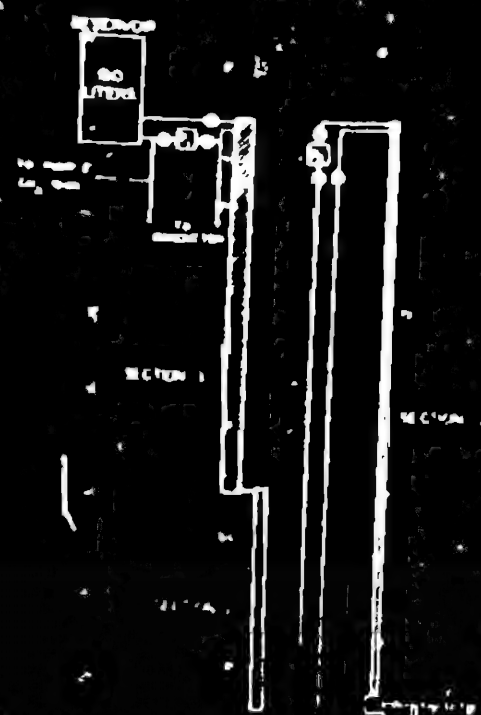


FIG. 1. Schematic drawing showing arrangement of sections of column.

hole in the iron cylinder and a similar valve in an obstruction in the brass tube insure the unidirectional flow of gas in the tube. The pumping speed of several cc per second is sufficient to maintain equilibrium between the column and reservoir.

Section 2 is connected directly to section 1 by means of a short brass tube (length=5 cm, diameter=1.8 cm). Because of the limited vertical space available section 3 is set next to 1 and 2 and is connected to 2 by two leads of  $\frac{1}{4}$ -inch copper refrigerator tubing one of which contains a pump  $P_2$  similar to  $P_1$ .

The construction of sections 2 and 3 was similar to that of 1 except that the steel tubing constituting the hot walls had sufficient thickness to eliminate the necessity for the extra tube used in section 1 to center the heating wire.

The methane is kindly supplied by the Southern California Gas Company and is over 99 percent pure. Every 48 hours 550 cc of gas is removed from the bottom by attaching a bulb at the point marked C between the valves. B is a small appendage which contains KOH pellets for the removal of  $CO_2$ . As the column is extremely efficient in separating heavy impurities in the methane the output is only approximately 75 percent methane. The equivalent steady drain of concentrated methane is thus 6.4 mg/hr. The  $C^{14}/C^{12}$  ratio in this is 14.8 percent. Every 8 days the contents of the upper reservoir are

TABLE II. Data on the three sections of column.

	No. 1	No. 2	No. 3
Length (ft.)	24	14	36
Length (cm)	730	427	1100
Diagrams (inches)			
Unrefined surface			
O. D.	6.375	0.750	0.375
I. D.	1.505	0.312	0.277
Refined surface			
O. D.	2.000	1.375	1.000
I. D.	0.936	1.291	0.900
Spacing of hot and cold walls (cm)	0.712	0.60	0.71
Annular circumference (cm)	22.5	19.13	22.5
Heating wire (No. 18 and 20 gauge)	24	24	24
Voltage (volts)	24	24	24
Current (amps)	25.2	21.0	15.0
Power (watts)	600	440	360
Temp. °C. Hot wall	300	385	387
Temp. °C. Cold wall	-27	-27	-27
$C^{14}$ (at. % of $C^{12}$ )	1.54	0.78	1.23
Volume of upper reservoir	150 liters		
Volume of lower reservoir	250 cc		

W. Kramers, *Phys. Rev.* 21, 1073 (1940).

changed after closing the valves between column and reservoir. The  $C^2$  in the reservoir is never depleted by more than 15 percent. The average  $C^1/C^2$  ratio in the reservoir is thus 0.0103. The average concentration produced by the column is hence 11.5 times

The  $C^1/C^2$  ratio at the top of section 3 is 0.030. Sections 1 and 2 together change the concentration by a factor of 2.9 whereas section 3 produces a change of 4.0 times.

These data are not sufficient to determine empirically both the separation factor  $\exp(2.1L)$  and the transport  $H$  for the different sections of the column. It is of interest, however, to compare the observed changes in concentration with those expected from theoretical considerations. The separation factor for the 24-foot section can be estimated from the empirical expression found earlier, i.e., (2) of §2.

This expression was obtained when the temperature difference between the walls was 500°C. Since the operating temperature difference is now about 350°C a slight change is necessary. The numerator and the first term in the denominator should be more or less independent of temperature, while the second term in the denominator should vary roughly as  $(T/\Delta T)e$ , where  $T$  is the mean temperature and  $\Delta T$  the temperature difference. The value of  $2.1L_1$  obtained from (3) with this correction from the change in temperature is noted in Table I. The same expression has been used to estimate the expected values for  $2.1L_2$  and  $2.1L_3$  for the second and third sections. The value of  $A$  for the third section was taken to be the same as the  $A$  for the first section. A correction for the difference in spacing ( $d$ ) was made in obtaining  $2.1L_2$  for the second section. These estimates assume that the correction for asymmetry in the temperature distribution is the same for all three columns. Without further information about the operation of the columns, this is probably as good a guess as any. The transport coefficients,  $H$ , as computed from the theoretical expression<sup>7</sup> of Furry, Jones and Onsager, are also listed for the three sections.

It is not difficult to compute from these values and a combine formula similar to (2) the

<sup>7</sup> Because of the numerous approximations made, it was not felt justified to correct  $H$ ,  $A$ , and  $Kp/K$  to allow for the cylindrical construction of columns. See W. H. Furry and R. C. Jones, *Phys. Rev.* **57**, 561 (1940).

concentration to be expected for any given rate of drain. If methane is drawn at a steady rate of 6.4 mg/hr., the calculations yield a concentration of 12.5 times for the whole column and of 3.0 for the first two sections, as compared with the observed 11.5 and 2.9, respectively. The calculated values are thus a little higher than those obtained in practice.

The discrepancy between practice and theory could be due to a number of factors. The rate of drain is not constant but intermittent. This means that each time a sample is removed the lower end of section 3 is disturbed abruptly. This disturbance is transmitted through the entire system. Also, no doubt, due to the action of the pumps there is a certain amount of remixing at the ends of the columns, a factor which would cut down the effective over-all length. In the previous work it was shown that in section 1 there was some remixing due to some asymmetry. It might well be true that this is different for 2 and 3 than for 1. The existing line voltage fluctuation of 4 percent would also contribute to the remixing. No account has been taken in the computations of the impurities.

This apparatus has been in continuous use since the fall of 1940 and has required practically no attention aside from time spent in removing the samples from the bottom and replenishing the gas at the top. It would thus be fair to state that including what little maintenance there is not over 15 hours per week of a man's time was needed.

Starting from scratch, it would probably be easier to build up the column by connecting standard sections in series and parallel. The third section which is 36 feet long may be a convenient choice. With two of these sections in parallel feeding a third in series, we compute a multiplication of 11.2 times for the same rate of drain as used above. With three sections in parallel feeding one in series the factor is 14 times. Probably the values obtained in practice would be somewhat less than these theoretical values as was true in the case investigated.

In the design of any new column one would, of course, choose the heating wires of such a size that an autotransformer would not be necessary as was the case for sections 1 and 2 of our set-up.

The authors are indebted to Mr. Rudolph Thorness for his skill in constructing and assembling the columns.



# On the Theory of Isotope Separation by Thermal Diffusion

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We here develop the theory of the processes in an apparatus with two concentric tubes, such as that used by Brewer and Bramley. In the first section we describe the process of thermal diffusion in general, and review the theoretical information on the subject. In Section II we set up the equations for the convection and diffusion processes, and obtain an expression for the net transport of a single isotope which is valid for arbitrary macroscopic properties of the gas. The assumption that the viscosity and heat conductivity of a gas are proportional to the absolute temperature is usually a good approximation; in this case the expression reduces to a simple form. In Section III

we apply the transport equation to questions of separation factor and speed of operation. This is done both for the case of discontinuous operation, in which the approach to equilibrium is allowed to reach a certain stage and then the contents of an end reservoir are removed, and for the case of operation with a continuous flow of gas through the tube. The advantages of the two methods are compared. In the last section we apply the formulas to a numerical example: the concentration of the  $C^{13}$  isotope by the use of methane, in an apparatus of moderate dimensions and power consumption.

## I. INTRODUCTION

RECENTLY Clusius and Dickel,<sup>1</sup> and subsequently Brewer and Bramley,<sup>2</sup> have reported the results of experimental work on the separation of isotopes by thermal diffusion. Their results suggest that this may become an important method. In this paper we discuss theoretically the problem of applying the process of thermal diffusion to isotope separation.

The phenomenon of thermal diffusion consists in the fact that a temperature gradient in a mixture of two gases gives rise to a gradient of the relative concentration of the two constituents. If the mixture as a whole is at rest, the equilibrium concentration gradient is such that the effect of thermal diffusion is just matched by the opposing effect of ordinary diffusion. The effect is by no means small; in some cases the coefficient of thermal diffusion may be as much as half of the ordinary coefficient.<sup>3</sup> A similar phenomenon is known in the case of liquids, where it is known as the Soret effect;<sup>4</sup> the theoretical explanation of the Soret effect has been signally unsuccessful.<sup>5</sup>

<sup>1</sup> K. Clusius and G. Dickel, *Naturwiss.* 26, 546 (1938).

<sup>2</sup> A. K. Brewer and A. Bramley, *Phys. Rev.* 55, 590A (1939).

<sup>3</sup> S. Chapman, *Phil. Trans.* A217, 184 (1917).

<sup>4</sup> Ludwig, *Wien. Akad. Ber.* 20, 539 (1856); Soret, *Ann. chim. Phys.* 22, 293 (1881).

<sup>5</sup> Wercide, *Ann. de physique* 2, 67 (1914); Porter, *Trans. Faraday Soc.* 23, 314 (1927). Also see comment by Chapman, *Phil. Mag.* 7, 1 (1929).

No simple theory can give an account of thermal diffusion; neither its existence nor its sign can be derived from elementary considerations.<sup>6</sup> Its presence can be understood only by a detailed consideration of the equations of transport in a gas. The phenomenon was completely overlooked by the classic workers in kinetic theory; it was first discovered theoretically by Enskog<sup>7</sup> in 1911, and independently by Chapman<sup>8</sup> six years later, and first demonstrated experimentally by Chapman and Dootson<sup>9</sup> in 1917.

The theory was fully and elegantly developed by Enskog,<sup>10</sup> and Chapman.<sup>8</sup> The more accessible treatment of Chapman is, however, unfortunately invalid because of algebraic errors.<sup>11</sup> Chapman's corrected result<sup>12</sup> may be shown to be identical with the result of Enskog. It is the result obtained by Enskog in his doctoral dissertation that is given in the well-known textbook of Müller-Pouillet.<sup>13</sup>

<sup>6</sup> S. Chapman, reference 5.

<sup>7</sup> D. Enskog, *Physik. Zeits.* 12, 56 and 533 (1911).

<sup>8</sup> Reference 3, p. 115.

<sup>9</sup> S. Chapman and F. W. Dootson, *Phil. Mag.* 33, 248 (1917), for a complete list of the experimental literature on thermal diffusion, see T. I. Hibbs, *Physica* 4, 1133 (1937).

<sup>10</sup> D. Enskog, *Doctoral Dissertation*, Upsala, 1917, published by Almqvist and Wikells.

<sup>11</sup> D. Enskog, *Arkiv. f. Mat., Astron., o. Fysik* 16, No. 16 (1921).

<sup>12</sup> S. Chapman and W. Hainsworth, *Phil. Mag.* 48, 593 (1924), the presentation of the value of  $D_T$  in this paper does not become complete until it is stated that the matrix  $a_{ij}$  is symmetrical.

<sup>13</sup> Müller-Pouillet, *Lehrbuch der Physik*, eleventh edition, Vol. 3, Part 2, p. 110.

but he did not consider the very effective method of fractionation employed by Clusius and Dickel.<sup>1</sup>

Clusius and Dickel ran a heated wire up the axis of a long vertical hollow tube, into which was put the gas whose isotopic constituents were to be separated. The combination of the effect of thermal diffusion and of the convection currents set up in the tube is such as to increase greatly the rather small separation caused directly by the radial temperature gradient. The light isotope collects at the top, while the heavy isotope goes to the bottom of the tube, as we shall discuss in detail in the next section.

The procedure of Brewer and Brumley<sup>2</sup> was very similar. They used two concentric tubes, of one and two centimeters diameter. The inner tube was heated.

In the following two sections we examine quantitatively what is occurring in this new method of separating isotopes. We find it possible to set up formulae showing the dependence of the performance characteristics on the dimensions of the apparatus, the temperature, the density, etc. These results should be useful in designing apparatus for isotope separation by this method.

## II. THE CONVECTION FIELD AND THE TRANSPORT EQUATION

### Description of apparatus and notation

The apparatus is supposed to consist of two concentric cylinders, the inner one heated and the outer one cooled, mounted in a vertical position, with reservoirs at the top and bottom communicating with the annular space between the cylinders, where convection and diffusion take place. The difference of the radii may be supposed small compared with either radius, so that we may proceed as if the convection were taking place in a thin flat slab, of breadth  $B$  equal to the mean circumference of the cylinders, thickness  $2\epsilon$  equal to the difference of the radii, and length  $2l$ , the length of the tube.

In addition to the notation already introduced, we shall use the following:  $T_1$ ,  $T_2$  = absolute temperature of the outer, inner tube;  $\Delta T = T_2 - T_1$ ;  $x$  = radial coordinate,  $-\epsilon < x < \epsilon$ ;  $z$  = coordinate along the tube,  $-l < z < l$ ;  $c$  = specific heat at constant pressure, in cal./gram-deg.;  $Q$  = heat

flow, in cal./cm<sup>2</sup>-sec.;  $\lambda$  = thermal conductivity, in cal./cm-deg.-sec.;  $p$  = pressure;  $\eta$  = viscosity;  $\rho$  = density;  $g$  = acceleration of gravity;  $J_1$ ,  $J_2$  = flux of species 1, 2 in grams/cm<sup>2</sup>-sec.;  $\tau$  = total upward transport, in grams/sec.;  $\tau_1$ ,  $\tau_2$  = upward transport of species 1, 2, in grams/sec.;  $\tau = \tau_1 + \tau_2$ ;  $c_1^0$  = value of  $c_1$  in the bottom reservoir;  $c_1^1$  = value of  $c_1$  in the top reservoir;  $c_1^e$  = equilibrium value of  $c_1$  with  $\tau = 0$ ;  $c_1^s$  = a specified value of  $c_1$ ;  $m_1$  = mass of gas in the top reservoir; and  $t_e$  = relaxation time of the equilibrium. In all considerations subsequent to Eq. (29), the temperature dependent quantities are to be evaluated at the average temperature  $\frac{1}{2}(T_2 + T_1)$ .

### General treatment of the convection and diffusion field

Throughout this section and the next it will be assumed that it is the lighter isotope, species 1, which can be separated by concentrating. The considerations will be completely symmetrical in respect to the interchange of 1 and 2, however, if we understand that the vertical coordinate changes sign when we apply our equations to the concentration of a heavy isotope (that is,  $c_1^0$  becomes the value of  $c_2$  in the top reservoir, while the small collecting reservoir would be at the bottom) and so on, in an obvious manner.

In the immediately following presentation, we shall develop a mathematical description of the convection and diffusion processes in the tube, and derive the fundamental relations which yield the transport of species 1 along the tube. Having obtained these relations, we then proceed in the next section to determine the behavior of the apparatus in the large, to find what separation factors can be obtained, and at what speed a mixture of given concentration may be produced.

We shall calculate the convection by using the temperature distribution as determined by conduction only. Near each end of the tube, where gas at a different temperature is entering, the temperature distribution is of course different. On the basis of the treatment of the convection problem given below, one finds that the length over which this difference remains appreciable is of the order of

$$l_c = (\epsilon^2/g\rho^2) 48\eta\lambda(T_2 - T_1)(T_2 + T_1) \quad (4)$$

where here as in (5) the temperature dependent



quantities  $\rho$ ,  $\eta$ ,  $\lambda$  are evaluated at the average temperature  $(T_2 + T_1)/2$ . Our neglect of these regions depends on the condition  $2l \ll 2L$ , which will usually be strongly satisfied in practice.

The treatment of the convection flow as lamellar is justified, since the Reynolds number may be shown to be roughly

$$\text{Re} \approx 24\eta^2(T_2 - T_1)/(l + T_1) \quad (5)$$

which in practical cases will be very much smaller than the values at which turbulence occurs in flow through tubes or between plates.

In the region of the tube where the temperature gradient is determined by conduction alone, we have

$$Q = \lambda l \frac{dT}{dz}$$

$$\sum_i Q_i = \int_{-l}^{+l} \lambda l \frac{dT}{dz} dz \quad (6)$$

$$Q = \lambda \frac{dT}{dz}$$

We shall neglect the dependence of  $\lambda$  on the concentration  $c$ , and also the dependence on  $c$  of  $\rho$ ,  $\eta$ , and  $D$ . These dependences are not large when the fractional difference of molecular weight is small. Moreover, only transverse differences have any significant effect on the performance, and the transverse difference of concentration is very small. Thus only the temperature dependences of the various quantities is of any importance.

The hydrodynamical equation of steady, viscous flow is

$$\eta \text{div } v - \text{grad } p = \eta \text{ grad } v \quad (7)$$

We assume that the velocity is entirely in the vertical direction, and that it is independent of  $z$ ; this is a very close approximation since the pressure variation within the tube is negligible. Then we have from (6) and (7),

$$(\eta \lambda) \frac{dT}{dz} (\eta \lambda) \frac{dT}{dz} = (\eta \lambda) \frac{dp}{dz} + \eta g \quad (8)$$

with the boundary conditions

$$T(T_1) = T(T_2) = 0 \quad (9)$$

By (1), the equation for the flux of species 1 is

$$J_1 = \rho[c_1 + D(-\text{grad } c_1 + \alpha c_1 \text{ grad } \ln T)] \quad (10)$$

and a corresponding equation holds for  $J_2$ .

We shall base our calculation of the transport of species 1 through the tube on the assumption that the time variation of the concentration  $c_1$  at each point in the tube is negligible—that is, that the condition is either stationary or quasi-stationary. A stationary condition exists at final equilibrium in a closed apparatus, and also when there is a uniform output of the concentrated isotope. During the approach to equilibrium the condition will be essentially stationary provided each end-reservoir is sufficiently large. The volume of each reservoir must be larger than that of a length of tube in which the equilibrium concentration changes by a factor  $e$ .

Accordingly we proceed from the equations

$$\text{div } J_1 = \text{div } J_2 = 0 \quad (11)$$

Eq. (10) then gives, on application of (6),

$$\frac{\partial}{\partial z} \left( \rho D \lambda \frac{\partial c_1}{\partial z} + \alpha c_1 \rho \frac{\partial T}{\partial z} \right) = 0 \quad (12)$$

The term containing  $\frac{\partial c_1}{\partial z}$  is the one that introduces the effect of longitudinal diffusion. The retention of this term would make it impossible to carry out the analysis in any simple manner. Since the effect of diffusion along the tube can be calculated separately quite accurately, we shall omit the term in question and calculate from

$$\frac{\partial}{\partial z} \left( \rho D \lambda \frac{\partial c_1}{\partial z} + \alpha c_1 \rho \frac{\partial T}{\partial z} \right) = 0 \quad (12')$$

We now introduce a function  $G(z, T)$  defined by

$$\frac{\partial}{\partial z} \left( \rho D \lambda \frac{\partial G}{\partial z} + \alpha G \rho \frac{\partial T}{\partial z} \right) = 0 \quad (13)$$

$$\rho D \lambda \frac{\partial G}{\partial z} + \alpha G \rho \frac{\partial T}{\partial z} = 0 \quad (13')$$

Then from (12')

$$\frac{\partial}{\partial z} \left( \rho D \lambda \frac{\partial c_1}{\partial z} + \alpha c_1 \rho \frac{\partial T}{\partial z} \right) = \frac{\partial}{\partial z} \left( \rho D \lambda \frac{\partial G}{\partial z} + \alpha G \rho \frac{\partial T}{\partial z} \right) \quad (14)$$

From this point on we shall assume that the dependence of  $\frac{\partial c_1}{\partial z}$  on  $T$  can be neglected. This is equivalent to assuming that  $\frac{\partial c_1}{\partial T}$  is independent of  $z$ , which is physically reasonable for a quasi-stationary condition. We shall at once establish two important consequences of this assumption: First, the total transport through the tube is zero; second,  $G$  is a function of  $T$  only.



Since  $\text{div. } J_1$  is zero, the flow of species 1 must be constant along the tube—that is,

$$v_1 = B \int_{-r_1}^{r_1} \rho c_1 v dz = \text{constant},$$

$$v_1 = (B/Q) \int_{-r_1}^{r_1} \lambda \rho c_1 v dz \quad (15)$$

$$(dv_1/dz) = (\partial c_1/\partial z)(B/Q) \int_{-r_1}^{r_1} \lambda \rho v dz \\ = (\partial c_1/\partial z) \cdot \tau = 0.$$

Then since  $\partial c_1/\partial z$  is not identically zero,  $\tau$ , the total transport, must vanish.

By (13a), we have

$$G(z, T_1) = G(z, T_2) = 0 \quad (16)$$

since  $J_{1z}$  must vanish at the walls. The factor  $(\partial c_1/\partial z)$  on each side of (14) cancels, and since the only remaining quantity that can be a function of  $z$  is  $G(z, T)$ , one finds, on integrating (14) that  $(\rho D/\lambda)G$  can depend on  $z$  only through an additive function of  $z$ . Then, since (16) holds identically in  $z$ , we have

$$G(z, T) = G(T) \quad (17)$$

We have now canceled the  $\partial c_1/\partial z$  in (14), and solving for  $v$ ,

$$v(T) = (1/\lambda \rho Q) \frac{d}{dT} (\rho D G(T)/\lambda) \quad (18)$$

Then from (18) and (16),

$$G'(T_1) = G'(T_2) = 0. \quad (19)$$

If we now substitute (18) in (8), and differentiate with respect to  $T$ , we obtain as the differential equation for  $G(T)$ ,

$$\frac{d}{dT} \left( \frac{1}{\lambda} \frac{d}{dT} \left( \frac{1}{\lambda} \frac{d}{dT} \left( \frac{\rho D}{\lambda} G(T) \right) \right) \right) = \frac{g}{dT} \quad (20)$$

with the boundary conditions

$$G(T_1) = G(T_2) = G'(T_1) = G'(T_2) = 0. \quad (21)$$

By the calculation of this single function one can, by (18), a complete description of the convection process; and, within the limits of our approximations, one has, by (13), a description of the transverse diffusion, both thermal and ordinary. By the use of this same function we can

proceed to obtain an expression for the transport of a single isotope along the tube.

According to (15) and (18) the net vertical transport of species 1 is

$$v_1 = (B/Q) \int_{-r_1}^{r_1} c_1 (d/dT) (\rho D G(T)/\lambda) dT \quad (22)$$

Partial integration and substitution from (13b) and (21) lead to the expression

$$v_1 = H c_1 - K \partial c_1 / \partial z, \quad (23)$$

where  $H$  and  $K$  are positive constants defined by

$$H = - (B/Q) \int_{-r_1}^{r_1} (\rho D/\lambda) G(T) dT \quad (24)$$

and

$$K = (B/Q) \int_{-r_1}^{r_1} (\rho D/\lambda) (G'(T))^2 dT \quad (25)$$

We have removed  $c_1$  from under the integral sign of (24), because  $c_1$  varies only slightly with  $T$ . We could not consider  $c_1$  as constant in (22), however, because it is only the slight variation of  $c_1$  which prevents this integral from vanishing.

In Eq. (23) the term  $H c_1$  gives the transport of species 1 caused by the existence, due to thermal diffusion, of a transverse flow of this isotope, which makes the concentration in the column of gas moving upward differ from that in the column moving downward. At the beginning of the process, when  $\partial c_1/\partial z = 0$ , this is the only cause of transport. After a longitudinal concentration gradient has been built up, the convection currents lead to a certain amount of remixing of the gas, represented by the term  $-K \partial c_1/\partial z$ . There is, however, another remixing effect which is not included in Eq. (23), because in replacing (12) by (12') we omitted the term which corresponds to diffusion along the tube. Since the convection velocity will be small, however, the longitudinal diffusion will be practically independent of it. If we ignore the convection velocity, the transport of species 1 due to longitudinal diffusion is

$$v_{1d} = -K_d \partial c_1 / \partial z, \quad (26)$$

$$K_d = (B/Q) \int_{-r_1}^{r_1} \lambda \rho D dz.$$

The total transport of species 1 is obtained by adding  $r_{11}$  to the  $r_1$  given by (23).

### Specialization to the Maxwellian case

The treatment so far has been general, in the sense that the quantities  $D$ ,  $\lambda$  and  $\eta$  might have an arbitrary temperature dependence. If, however, the mean free path varies as the  $(n-1)$ th power of the temperature, and if  $c_s$  is independent of  $T$ , the following quantities should all be constant:

$$(\eta/T^n), (\lambda/T^n), (\rho D/T^n); (\eta/\lambda), (\rho D/\lambda).$$

Then (20) becomes

$$(d/dT)T^{-n}(d^2/dT^2)T^{n-1}(dG/dT) = -T^{-2}(\lambda^2 \rho g)(\eta D T^{n-2}). \quad (27)$$

The general solution of (27) has been obtained, and there appears to be no bar to the explicit evaluation of  $H$  and  $K$  in this manner. The formulae would be awkward in practice, however, because of heavy cancellation of terms. The writers have worked out the cases of  $n=1/2$  (hard spheres) and  $n=1$  (Maxwellian molecules). Since the case  $n=1$  is much simpler than any other, and corresponds fairly well to the temperature dependence of the properties of most gases, we suggest that the formulas for this case be used in practice. This simplification is particularly well justified because our knowledge of the all-important factor  $\alpha$  itself is so inexact.

For  $n=1$ , integration of (27) and application of (21) gives

$$G(T) = -\{(\lambda^2 \rho g)/(24\eta D)\} \times (T_2 - T)^2(T_1 - T)^2/(T_2 + T_1). \quad (28)$$

and (6) becomes

$$w = \lambda \Delta T / 2Q. \quad (29)$$

where in this and all following formulae,  $\rho$ ,  $D$ ,  $\lambda$ ,  $\eta$  and  $T$  are to be evaluated at  $T = \frac{1}{2}(T_2 + T_1)$ . If (28) and (29) are used in (24), the result is

$$H = \{(\lambda^2 \rho g B)/(90\eta)\} (\Delta T/T)^2 f(\Delta T/T), \quad (30)$$

where

$$\begin{aligned} f(\Delta T/T) &= 30T^2(\Delta T)^{-1}[(\Delta T)^2/6 - T_1 T_2 \\ &\quad + (T_1 T_2)^2(T\Delta T)^{-1} \ln(T_2/T_1)] \\ &= 15 \sum_k (\Delta T/2T)^{2k} / [(2k+1)(2k+3) \\ &\quad \times (2k+5)] \\ &= 1 + (15/3 \cdot 5 \cdot 7)(\Delta T/2T)^2 + \dots \end{aligned}$$

$f(\Delta T/T)$  has the value unity for  $\Delta T=0$ , and the value  $5/4$  for the extreme case  $T_2/T_1=0$ , and lies between these two values for intermediate cases. For  $T_2=2T_1$ ,  $f=1.016$ , while for  $T_2=3T_1$ ,  $f=1.039$ .

From (25) and (29), we have

$$A = H, 2K = (63/4) \times \{(\alpha \eta D)/(\rho g \alpha^2)\} f(\Delta T/T). \quad (31)$$

and (26) gives

$$K_d/K = 1890(T_1^2 + T_1 T_2 + T_2^2) \times \{D\eta/(\pi^2 \rho g \Delta T)\}^2. \quad (32)$$

The corresponding relations for a gas consisting of hard spheres follow.

We introduce the abbreviations

$$\begin{aligned} t &= T_1, \quad t_1 = T_1, \quad t_2 = T_2, \\ r &= (t_2 - t_1)/(t_2 + t_1), \\ s &= (2t - t_2 - t_1)/(t_2 - t_1). \end{aligned}$$

Then we find

$$\begin{aligned} G(T) &= -\{(\lambda^2 \rho g T)/(72\eta D)\} \{t_2 - t_1\}^2 \{1 - (s/r)^2\}^2 \\ &\quad \times \{10 - 2r^2(3+r)^2 - (3+r)^2(3+r^2)(5-r^2)^{-1}\}, \\ w &= \{(\lambda/3QT)\} \{t_2 - t_1\}, \\ H &= \{(\lambda^2 \rho g T)/(3Q\eta)\} \\ &\quad \times \{t_2 - t_1\}^2 \{t_2 + t_1\} \{3+r^2\} \{5-r^2\} \psi(r), \\ \psi(r) &= 1 - r^2 \{5 - (30+2r^2) \\ &\quad \times \{r^2(1+3 \cdot 5 \cdot 7) + r^4(13 \cdot 5 \cdot 7 \cdot 9) + \dots\}\}, \\ \psi(0) &= 1, \quad \psi(1) = 4/9, \\ K &= \{(\lambda^2 \rho g T^2)/(63Q\eta D)\} \\ &\quad \times \{t_2 - t_1\}^2 \{t_2 + t_1\} \{3+r^2\} \{5-r^2\} \psi(r), \\ \phi(r) &= 1 - (602/825)r^2 + (146/2475)r^4 \\ &\quad + (4/75)r^6 + (13/7425)r^8, \\ \phi(0) &= 1, \quad \phi(1) = (2044/7425), \\ K_d &= \{(\lambda^2 D)/(2QT)\} \{t_2 - t_1\}. \end{aligned}$$

In some cases the ratio (32) will be quite small, so that (23) gives essentially the total transport. For example, with fixed dimensions of apparatus this will be true provided the pressure is sufficiently high ( $(\rho/D) \propto (\text{pressure})^n$ ). For the sake of simplicity we shall proceed with most of



our considerations on the assumption that this condition  $(K_1/K) \ll 1$ , is satisfied. In cases where this is not true, it is only necessary to replace  $A$  in the following by

$$A_1 = A / [1 + (K_1/K)]. \quad (33)$$

### III. SEPARATION FACTOR AND SPEED OF OPERATION

#### Discontinuous operation

We shall now apply the results we have just derived to the case of *discontinuous* operation, by which is meant that one waits until the upper reservoir has approached its equilibrium concentration, and then removes all of its contents, and starts over again. It is assumed that the reservoir is closed off from the tube during the removal of the gas; otherwise the mixing with gas drawn in from the tube would make it impossible to obtain the concentrations and amounts calculated here.

Our fundamental equation for these calculations is that for the total transport of species 1 up the tube. By (23) and (31) we have

$$r_1 = H_1 c_1 (1 - c_1) - (2A)^{-1} (dc_1/dz). \quad (34)$$

At the final equilibrium, when the concentration in the top reservoir has ceased to increase,  $r_1 = 0$ , and the solution of (34) is

$$c_1(z) = \frac{1}{2} [1 + \tanh A(z - z_0)]. \quad (35)$$

where  $z_0$  is determined by the condition that the total quantity of species 1 is conserved. If we set

$$c_1(-l) = c_1^0; \quad c_1(l) = \kappa, \quad (36)$$

we find for the equilibrium separation factor:

$$\kappa/c_1^0 = (1 - c_1^0)/(1 - \kappa) = e^{2Al}. \quad (37)$$

If  $\kappa$  is small with respect to unity, this becomes

$$(\kappa/c_1^0) \approx e^{2Al}. \quad (38)$$

When  $r_1$  is not zero, but has some constant value—that is, before the final equilibrium has been established—the solution of (34) is

$$c_1(z) = \frac{1}{2} [1 + g \tanh qA(z - z_0)], \quad (39)$$

where  $g = (1 - 4r_1/H)^{1/2}$ .

Under the boundary conditions  $c_1(-l) = c_1^0$ ,

$c_1(l) = c_1^1$  we have now

$$c_1^1 = \frac{1}{2} - (g/2) [q \tanh 2qAl - q_0] / \times [q_0 \tanh 2qAl - q], \quad (40)$$

where  $q_0 = 1 - 2c_1^0$ .

In practice, it will be advantageous to make the lower reservoir sufficiently large that  $c_1^0$  does not drop appreciably during the separation, since if it should drop, one would not realize all of the separation factor. If the reservoir is sufficiently large, then,  $c_1^0$  is also the initial concentration of species 1. The constancy of  $c_1^0$  may often be secured more conveniently by maintaining a continuous flow through the bottom reservoir. The quantity  $q_0$  is then constant and equal to the initial value of  $q$ , and the equation for the time rate of change of  $c_1^1$  is

$$(dc_1^1/dt) = r_1/m_1. \quad (41)$$

Let  $t(\kappa)$  be the time for the concentration of the top reservoir to rise from its initial value  $c_1^0$  to some required value  $\kappa$ . The integral of (41) may then be expressed as

$$t(\kappa) = m_1 \int_{c_1^0}^{\kappa} dc_1^1 / r_1. \quad (42)$$

The integral must be done numerically or graphically, by calculating  $c_1^1$  from (40) for several values of  $r_1$ .

In many cases, however, a close approximation can be used, which eliminates the necessity of numerical integration. We note that

$$c_1(1 - c_1) \approx c_1(1 - 2c_1^0) + (c_1^0)^2 - (c_1 - c_1^0)^2 \quad (43)$$

where  $c_1^0$  is arbitrary. If  $\kappa$  differs from  $c_1^0$  by only a small amount, say not more than 0.2 or 0.3, one can select a value of  $c_1^0$  and a constant to replace the last term in (43) in such a way that the resulting linear expression is a good approximation to  $c_1(1 - c_1)$  throughout the range in question. If in (34) the quantity  $c_1(1 - c_1)$  is replaced by such a linear approximation, then (34) and (41) can be integrated explicitly, and the formula for  $c_1^1$  so obtained represents a simple exponential approach to equilibrium, which can be characterized by a relaxation time. This gives us a useful way to describe the speed of operation for cases in which a linear approximation to (43) is valid. In the case that the



range of  $c_1$  is larger than about 0.3, the approach to equilibrium is of a more complicated type, which can not be characterized even approximately by a relaxation time.

A suitable value for  $c_1^*$  is the mean value of  $c_1^*$  and  $\kappa_1$ . In the present case, the constant value inserted in place of  $(c_1 - c_1^*)^2$  will not appear in the relaxation time; then by the procedure outlined, we find a relaxation time (time for  $c_1^* - c_1^0$  to rise to  $1 - e^{-1}$  of its equilibrium value).

$$t \approx (m_1 H / c_1^* \tau_1) (1 - c_1^0 / c_1^*) \quad (44)$$

There are several special cases of (44) worth mentioning. If  $c_1$  is always small compared to unity,

$$t \approx m_1 H / c_1^* \tau_1 \quad (45)$$

If the separation factor, which is  $c_1^0$  in this case, is much larger than one, we see that the relaxation time is directly proportional to the separation factor.

If, however, we are working in the middle region, where both  $c_1^0$  and  $\kappa_1$  are approximately one-half,

$$t \approx 4.1 m_1 H / \tau_1 \quad (46)$$

while if  $c_1$  is always close to unity,

$$t \approx (m_1 H / \tau_1) (1 - c_1^0) \quad (47)$$

It may perhaps be possible in practice to reduce the equilibrium time to some extent by a suitable variation of the pressure during operation. From (30) and (31) we see that  $H$  and  $K$  vary, respectively, as the second and fourth powers of the pressure. According to (23) the transport of species 1 is determined essentially by  $H$  during the early part of the separation process, while  $\partial c_1 / \partial z$  is still small. Thus a high pressure at the beginning increases the transport. In order to reach a large concentration gradient finally, the pressure must be reduced again. By proper manipulation a considerable advantage might be obtained. Such a procedure, however, meets a considerable technical difficulty, since the volume of the upper reservoir would have to be varied along with the pressure in order to prevent the loss of a great deal of gas down the tube.

### Continuous operation

So far we have been discussing operation with no total transport of gas through the tube. In such operation the concentrated material is obtained by waiting until the approach to equilibrium has reached a certain stage, and then removing the contents of the top reservoir. There is also available a continuous type of operation, in which a small steady flow of gas is removed from the top of the apparatus, so that there is a small total transport of gas along the tube.

The convection field with which we have been calculating, which is described by the function  $G(z)$ , provides no total transport along the tube. Because of the linearity of the hydrodynamical equation, however, we can superpose on the convection field an unidirectional velocity field corresponding to a very small additional pressure difference. Since the additional velocity field is unidirectional and  $c_1$  varies only very slightly across the tube, we can omit all discussion of the details of the new field and the distribution of  $c_1$  across the tube; we simply write for the transport of species 1 due to the new field the product of the mean value of  $c_1$  at the given position along the tube and the total transport of gas. The total transport of species 1 is then

$$H \bar{c}_1 = K \bar{c}_1 d^2 / 4 \tau_1 \quad (48)$$

where  $\bar{c}_1$  is now constant along the tube. The quantities  $H$  and  $K$  may still be taken as defined by (30) and (31); since, with attainable speeds of operation, the velocities in the superposed unidirectional field will in practice be extremely small.

As before we introduce  $A = H / 2K$ , and as a convenient dimensionless parameter,

$$n = \tau_1 H \quad (49)$$

We shall treat only the equilibrium case, where  $\tau_1$  has a constant value,  $\kappa_1$ . There is little value in treating the approach to the new equilibrium, because the apparatus presumably would be operated with  $\tau = 0$  until  $c_1$  rose to the value intended for continuous operation. Then we have  $\tau_1 / \tau = \kappa_1$ , and therefore

$$\tau_1 = n / \kappa_1 \quad (50)$$

The differential equation for  $c_1$  is now

$$j - r_1^2 + (1+n)c_1 - n\kappa_1 \cdot \frac{1}{2} dc_1 = 2A dz, \quad (51)$$

whose solution is

$$c_1(z) = \frac{1}{2} [1+n+q' \tanh q'A(z-z_0)], \quad (52)$$

where

$$q' = \frac{1}{2} [(1+n)^2 - 4n\kappa_1]^{1/2}.$$

Eliminating  $z_0$  by the condition  $c_1(-l) = c_1^0$ ,  $c_1(l) = \kappa_1$ , we find

$$\tanh 2q'A = q'(\kappa_1 - c_1^0) / \frac{1}{2}(1+n)\kappa_1. \quad (53)$$

This rather formidable equation gives the important relation between  $r$  and  $\kappa$ . It must be solved in any given case by successive approximations. The procedure may usually be based on the assumption that  $n$  is small, since only for small values of  $n$  can a large separation factor be realized. If, for example, one replaces  $q'$  by unity in the left member, and by the linear approximation  $1+n(1-2\kappa_1)$  in the right member, one obtains as a first approximation

$$\frac{1}{2}(\kappa_1 + c_1^0 - 2\kappa_1 c_1^0) \tanh 2Al = (\kappa_1 - c_1^0) \times (\kappa_1 - c_1^0)^{-1} (1 + \tanh 2Al - 2\kappa_1)^{-1}. \quad (54)$$

The quantity  $q'$  can then be calculated with the value  $n^{(1)}$  for  $n$ , and (53) can then be solved for the second approximation  $n^{(2)}$ , and so on. This particular procedure converges well if  $c_1^0$  is small, but fails entirely if  $c_1^0 \geq \frac{1}{2}$ .

For cases in which the range of values of  $c_1$  to be covered is small, one can simplify the analysis by replacing  $c_1 c_2$  in (48) by a linear expression in  $c_1$ , just as was done in obtaining Eqs. (44)–(47) for discontinuous operation. In the present case the resulting formula involves the parameters of the linear expression in a more complicated way than does (44). Simple formulas can be given, however, for each of the three special cases corresponding to (45)–(47). When  $c_1$  remains fairly small throughout, we can replace  $c_1 c_2$  by  $c_1 \kappa_2$  in (48), and, remembering that  $n$  must be small, we obtain

$$(c_1/c_1^0) \leq (e^{-4Al} + n)^{-1}. \quad (55)$$

For cases in which  $c_1$  is throughout in a range

of values of perhaps 0.3 to 0.7, we can replace  $c_1 c_2$  by  $\frac{1}{4}$ , and find

$$(c_1 - c_1^0) \leq (1 - e^{-4Al})/4n. \quad (56)$$

When  $(1 - c_1)$  remains fairly small, we can replace  $c_1 c_2$  by  $1 - c_1$  in (48), and obtain

$$(1 - c_1^0)/(1 - c_1) \leq (e^{4Al} - 1 - n)/(1 - n). \quad (57)$$

These three formulas correspond precisely to (45), (46) and (47), respectively, and involve just the same linear approximations.

Continuous operation is the only practical method if we wish to use several stages in series, and the use of multi-stage apparatus seems distinctly desirable if we wish to combine a large separation factor with large speed of production. We have seen that if  $c_1^0$  is small, the quantity  $n = r/H$  must be small compared to unity. Therefore, in any stage, the transport is effectively limited by the quantity  $Hc_1^0(1 - c_1^0)$ , where  $c_1^0$  is the concentration at the bottom of the stage in question. If, now,  $c_1^0$  is small, we see that in order to obtain a transport equal to that of a later stage,  $H$  must be larger for the first stage. A large  $H$ , however, means either a large  $K$ , and then the separation will be small, or a large  $B$ . A compromise would probably be used in practice.

The multi-stage apparatus should therefore consist of a series of vertical tubes; the first tube should be of large size and will produce a small change of concentration; subsequent tubes should be made progressively smaller.

#### Comparison of the two types of operation in single-stage apparatus

In the case of small  $c_1$ , formulas (45) and (55) make possible a simple direct comparison of the separations obtained by the two methods at a given effective speed, provided that  $4Al$  is large enough so that  $e^{-4Al}$  can be neglected compared to unity. Eq. (55) can be written

$$(c_1/c_1^0) \leq [1/(1+\theta)]e^{4Al}, \quad (58)$$

where

$$\theta = n - e^{-4Al} = (H/r)e^{-4Al} \quad (59)$$

is a parameter inversely proportional to the speed, and  $e^{4Al}$  is the equilibrium separation given by (38), which may also be obtained by



setting  $n=0$ , or  $\theta \rightarrow \infty$ . In *discontinuous* operation the quantity which corresponds to  $\tau$  is  $m_1/l_0$ , where  $l_0$  is the time allowed for the separation to approach equilibrium before the reservoir is emptied. Then if we put

$$\theta' = H/l_0 (m_1 c_1^{(0)}) \quad (59')$$

equal values of  $\theta$  and  $\theta'$  correspond to equal effective speeds of production by the two methods. According to Eq. (45), the exponential approach to equilibrium now takes essentially the form

$$(x_1 - c_1^{(0)}) = (1 - e^{-\theta'}) e^{c_1^{(0)}} \quad (60)$$

The expressions (58) and (60) show that at a given effective speed a greater fraction of the equilibrium separation ratio can be obtained by using discontinuous operation.

In the case of  $c_1$  near one-half, we can introduce the parameters

$$\zeta = (4.4/m)^{-1/2}; \quad \zeta' = H/l_0 (4.4/m)^{-1/2} \quad (61)$$

equal values of  $\zeta$  which correspond to equal effective speeds. The equilibrium concentration difference, from (56) with  $n=0$  is  $AL$ ; and the realized concentration differences are, by (56) and (46),

$$(x_1 - c_1^{(0)}) \leq (1 - e^{-\zeta}) AL \quad (62)$$

for continuous operation, and

$$(x_1 - c_1^{(0)}) \leq (1 - e^{-\zeta'}) AL \quad (63)$$

When less than a fraction  $(1 - e^{-\zeta})$  of the equilibrium concentration difference is to be obtained, the continuous method works slightly better; otherwise, the discontinuous is better.

In the remaining case,  $c_1$  nearly equal to one, it is not possible to introduce a single parameter characterizing the speed in such a way that a simple comparison of the two methods is possible. Rough computation from (47) and (57) shows that when large ratios  $(1 - c_1^{(0)})/(1 - \alpha_1)$  are required, continuous operation is decidedly faster.

#### General remarks on speed of operation

In the case of discontinuous operation, the quantity which characterizes the speed of operation in terms of the mass of the element with a given concentration, divided by the time required to produce it, is  $m f/l_0$ , where  $f$  is the

fraction of the molecular weight contributed by the element in question. This characteristic quantity varies as  $Hf$ . In the continuous case, the corresponding quantity is  $\tau f$ , which, for a given concentration, also varies as  $Hf$ . Thus in either case the variation of the speed,  $f$ , is given by

$$f \propto Hf \propto (u^2 \rho^2 \alpha B f / \eta) (\Delta T / T)^2 \quad (64)$$

Since  $AL$  must have a given value, and since  $D \propto \eta / \rho$ , we see from (31) that  $w$  must vary as

$$w \propto (\alpha l)^{1/2} (\eta / \rho)^{1/2} \quad (65)$$

If we accept (3),  $\alpha$  varies as  $f$ , and we have the significant relation

$$f \propto f^{7/10} l^{3/10} (\rho \eta)^{1/2} B (\Delta T / T)^2 \quad (66)$$

To get a large speed at the specified concentration, it is evident that one should choose as light a molecule as possible, because of the strong dependence on  $f$ . The factor  $B$  can be increased by using a larger tube, or several tubes in parallel. Since under ordinary conditions  $\rho$  is proportional to the pressure, the speed varies as the square root of the pressure and as the three-fourths power of the length, *provided* that  $2\pi a$ , the difference of the radii, is readjusted for changes of pressure and length in accordance with (65).

It is assumed in the argument leading to (66) that the ratio  $K_2/K$  is very small compared with unity, since otherwise we should not be justified in using (31), and should use instead the modified value (33).

The power expended because of conduction is by (29)

$$P_c = 2lB + 18Q = 4.18N/B\Delta T w \quad (67)$$

in watts, and, by (65), is proportional to  $l^2 \rho^{1/2} B \Delta T$ ; the viscosity and heat conductivity are independent of the pressure. Thus so far as conduction is concerned, the speed and power are just proportional to one another, as long as a fixed concentration difference is demanded, and a fixed temperature difference is used. The advantage of a rather large  $\Delta T$  is evident; but there is little use in going to extreme temperatures, since it is the ratio of  $\Delta T$  to the mean temperature that is involved, and also since the radiation loss will be large if  $T_2$  is made very



high. The power consumption due to radiation between the walls is independent of  $w$ , and for nontransparent tubes is given by

$$P_r = 2lB(1 - R_1)(1 - R_2) \times (1 - R_1 R_2)^{-1} \sigma (T_1^4 - T_2^4), \quad (68)$$

where  $R_1$  and  $R_2$  are the average reflection coefficients of the walls of the tubes, and  $\sigma = 5.7 \times 10^{-12}$  watt/cm<sup>2</sup>-deg.<sup>4</sup>.

#### Effects of asymmetry; general constructional considerations

We shall here consider briefly the effect of asymmetry in the apparatus. Due to non-uniformity of heating or cooling of the tubes, it is possible that the temperature may vary around the tube. This will give rise to an additional convection, characterized by a slight upward flow at the hotter part of the annulus, and a corresponding downward flow at the colder part. For simplicity, we may suppose that the temperature field is still independent of  $z$ , but varies with the azimuthal angle,  $\varphi$ , in the simple manner:

$$T = f(r) + (\delta T/2) \cos \varphi. \quad (69)$$

One can then show that the essential effect is to introduce another contribution to the transport given by  $-K_r dr_1/dz$ , where

$$K_r = (315B^2/16\pi^2 w^2) (\delta T/\Delta T) \epsilon, \quad (70)$$

provided that  $B \gg w$ . Since  $K_r$ ,  $K$  must be kept fairly small, Eq. (70) imposes rather strong conditions on the tolerable asymmetry of the temperature. In the apparatus to be discussed in the next section,  $K_r$  would become equal to  $K$  for  $\delta T \leq 5^\circ$ .

A lack of centering of the tubes would have a considerable direct effect on performance, because  $H$  and  $K$  depend on the third and seventh powers of  $w$ . The asymmetry in temperature brought about by the lack of centering would, if appreciable, be still more harmful. To minimize it, good conduction is essential. Thus metal tubes are to be preferred on several counts: for precision in construction, high conductivity, and large reflection coefficient to reduce radiation losses.

The importance of symmetry makes it evident that advantages in speed and concentration

should be sought by increases in length rather than by the use of high pressures and small values of  $w$ . Also, both for accuracy of construction and because of the factor  $B^2$  in (70), it is better to use several tubes in parallel rather than large tubes.

To avoid lack of symmetry in the temperature distribution, the water cooling must be efficient and the heating of the inner tube must be very uniform. Heating by condensation of a vapor rather than by resistance wire seems advisable.

#### IV. A NUMERICAL EXAMPLE: C<sup>13</sup>

In order to illustrate the application of our formulas we shall apply them to the design of a single-stage apparatus for the concentration of C<sup>13</sup>. Here we are concerned with the concentration of a heavy isotope at the bottom of the tube. Our equation for  $A$  and all our equations concerned with the speed of operation apply here with no change except the replacement of  $c_1$  by  $c_2$ . A formal justification of this rule is provided by inspection of the fundamental equations (23) and (48). In these equations we must interchange  $c_1$  and  $c_2$ ; change the sign of the term in  $c_1 c_2$ , since this term changes sign in rewriting (10) for species 2; and change the signs of the  $\tau$  and  $\tau_1$  terms, because we are now concerned with transport down the tube. When this is done the equations are unchanged in form except for a change in sign of the term in  $\partial/\partial z$ . This is proper, since the concentration is now increasing downward instead of upward.

We take as the specifications of our apparatus: Length of tube,  $2l = 800$  cm;  $B = 2\pi r = 4\pi$ ;  $T_1 = 300^\circ\text{K}$ ;  $T_2 = 600^\circ\text{K}$ ; pressure, 1 atmosphere; and equilibrium concentration,  $\epsilon_e = 0.30$ . Since the carbon isotope of mass 13 occurs with a natural abundance<sup>16</sup> of one part in about 92, and therefore  $c_1^0 = 0.0108$ , it follows at once from (37) that we must have  $e^{A/l} = 39.3$ , or  $A = 0.0023/\text{cm}$ .

The required value of the difference in radii,  $2w$ , and the speed of operation are now determinate, once we have selected the molecule which is to carry the carbon.

Our general discussion of the speed shows

<sup>16</sup> Vaughan, Williams and Tate, *Phys. Rev.* **46**, 327(A) (1934).

that determined by conduction is of the order of 0.4 cm, and thus may certainly be neglected.

The calculations given above for  $C_D$  are based on the value  $\alpha = 0.0106$  which is given by eq. (3). This equation is, however, only a rough guess, albeit the best one possible. It may be found by experiment that the actual values of  $H$  and  $A$  for any given gas are distinctly different from those calculated from values of  $\alpha$  given by (3), perhaps by as much as a factor 2. In practice, therefore, it will be necessary to do some preliminary work to find the actual value of  $\alpha$ . It is suggested that this be done by running the apparatus at a fairly high pressure. For instance, in the example just discussed, the use of a pressure of two atmospheres instead of one will multiply  $H$  by 4, and divide  $A$  by approximately 4, so that the separation factor will be small, but so will also be the equilibrium time. If one now measures  $C_D$  as a function of the time, one will obtain the values of both  $H$  and  $A$ . Either one will yield the value of  $\alpha$ , by (30), or by (31),

(32) and (33). We may now extrapolate  $A$  to the desired value by changing the pressure, since we know that  $H$ ,  $A$  and  $K$ ,  $K$  vary, respectively, as the second, inverse second, and inverse fourth power of the pressure.

Preliminary adjustments such as those just described will of course be necessary only in the first work on each gas. Once the correct value of  $\alpha$  is known from experiment, our equations should make it possible to design apparatus which will perform in acceptable agreement with specifications.

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### Calculation of the Second Virial Coefficient of Helium Gas for the Lowest Measured Temperature

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IN RECENT articles<sup>1</sup> an explicit and calculable expression has been derived for the second virial coefficient of a monatomic gas. This is the  $B$  in the equation of state,

$$pV/RT = (1 + B(T)/V + C(T)/V^2 + \dots)$$

and, assuming the Einstein-Bose statistics, is given by the formula,

$$B_{E.B.} = -\frac{N\sigma\lambda^2}{2} - 16N\sigma \sum_{l=0}^{\infty} (l+1) \times \exp[\lambda^2 k_0^2(\eta, l)/a_0^2] - 16\sigma^2 N \lambda^2 \sum_{l=0}^{\infty} (l+1) \int_0^{\infty} dk_0 \times \exp[-\lambda^2 k_0^2/a_0^2] (d\eta/dk_0). \quad (1)$$

<sup>1</sup> E. Beth and G. E. Uhlenbeck, *Physica* 4, 915 (1937); L. Gropper, *Phys. Rev.* 51, 1108 (1937).

Here,  $\lambda^2 = h^2/mkT$ ,  $\eta$  is the phase found from the wave equation for the relative motion of two radially interacting molecules,

$$\frac{d^2v}{d\rho^2} + \left( k_0^2 - \frac{m}{h^2} a_0^2 l' - \frac{l(l+1)}{\rho^2} \right) v = 0.$$

$k_0^2(\eta, l)$  are the discrete states for two such molecules,  $a_0$  is the Bohr radius, and  $l'$  is the interaction potential between the two molecules.

Extensive calculations have recently been made with formula (1) by Massey and Buckingham<sup>2</sup> on the inert gases, in particular, helium. These calculations are based on the use of the Slater-Kirkwood potential for the calculation of

<sup>2</sup> H. S. W. Massey, and R. A. Buckingham, *Proc. Roy. Soc.* 168, 378 (1938).